Aalto University
School of Engineering

Juha Pennala

Update of Finnish *in situ* Rock Stress Data

Master's thesis

Espoo 4.12.2017
Supervisor: Professor Mikael Rinne
Instructor: D.Sc. Topias Siren

Aalto University
School of Engineering

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

Abstract of master's thesis

Author B.Sc. Juha Pennala

Title of thesis Update of Finnish *in situ* Rock Stress Data

Degree programme Transportation and Environmental Engineering

Major/minor Foundation and Rock Engineering / Environmental Geology and Applied Geophysics **Code** IA3028

Thesis supervisor Professor Mikael Rinne

Thesis advisor(s) D.Sc. Topias Siren

Date 4.12.2017 **Number of pages** 63 **Language** English

Abstract

The bedrock of Earth's crust is in heterogeneous three-dimensional stress state due to geological processes. Stress state of rock is one of the key rock mechanics factors related to the safety and stability of underground excavations for mining and civil engineering purposes. The aim of this thesis is to collect Finnish *in situ* rock stress field measurement data and to update the worldwide World Stress Map open database. The Finnish data has been updated last time in year 1999. The project is also a start for Finland to join developing new under development database, the Quantitative World Stress Map. Data is being prepared also to the needs of new database while the new database structure is still in development.

In situ stress measurements have been made in Finland mainly using hydraulic fracturing, overcoring and LVDT-method. Significance of traditional overcoring method has decreased evidently since the 1990s. New LVDT-method has been developed during the 2000s to solve earlier problems and inaccuracies.

In the thesis the measurement data has been collected from publicly available sources, such as a Finnish Nuclear Waste Management Company, Posiva Oy, and from private sources, such as mining companies and tunnel engineering projects. Information from reports is separated and compiled suitable for databases. About 150 new Finnish stress state compilations have been analyzed and prepared as new data records to World Stress Map database. Compilations have been prepared from about 1400 separate measurements, which are usable also for the new quantitative database.

Different uncertainties in measurements and dispersion of data hinder the overall quality of the stress measurements. Reasons of dispersion and different failures are not always possible to find out disturbing the reliability of results. Development of measurement methods and improvement of equipment improve accuracy and confidence of stress measurements and onwards significance of stress measurements in planning. As an example of the development is the integration of multiple measurements, 3D modelling and inversion calculation in LVDT-method.

In situ stress measurement methods and understanding of rock stress is developing constantly. The newest data of Finnish *in situ* stress measurements help mining and civil engineering to increase the understanding of Finnish rock stress.

Keywords *In situ* rock stress, stress measurement, World Stress Map, hydraulic fracturing, overcoring, LVDT-method

Aalto-yliopisto
Insinööritieteiden korkeakoulu

Aalto-yliopisto, PL 11000, 00076 AALTO
www.aalto.fi

Diplomityön tiivistelmä

Tekijä B.Sc. Juha Pennala

Työn nimi Suomen kallioperän jännitystilamittaustietojen päivitys

Koulutusohjelma Yhdyskunta- ja ympäristötekniikan koulutusohjelma

Pää-/sivuaine Pohja- ja kalliorakentaminen / Teknillinen geologia ja sovellettu geofysiikka **Koodi** IA3028

Työn valvoja Professor Mikael Rinne

Työn ohjaaja(t) D.Sc. Topias Siren

Päivämäärä 4.12.2017 **Sivumäärä** 63 **Kieli** Englanti

Tiivistelmä

Maankuoren kallioperä on heterogeenisessa kolmiulotteisessa jännitystilassa litosfäärilaattojen liikkeistä johtuen. Kallioperän jännitystilan suunnat ja suuruudet ovat tärkeitä tietoja kallioon rakennettaessa. Tämän diplomityön tavoitteena on päivittää tiedot Suomessa tehdyistä jännitystilamittauksista keräämällä tietoja ja päivittämällä avointa maailmanlaajuista jännitystilatietokantaa. Edellisen kerran Suomen tietoja tietokannassa on päivitetty vuonna 1999. Projekti on ollut myös Suomen avaus osallistua uuden kehitteillä olevan kvantitatiivisen jännitystilatietokannan kehitykseen. Tietoja on valmisteltu myös uuden tietokannan tarpeisiin uuden tietokantarakenteen ollessa edelleen kehityksessä.

In situ jännitystilan mittauksia on tehty Suomessa pääasiassa hydraulisella murtamisella, irtikairauksella ja LVDT-menetelmällä. Perinteisten irtikairausten merkitys on vähentynyt selvästi vuosituhannen jälkeen. Uusi aikaisempia ongelmia ja epätarkkuuksia korjannut LVDT-menetelmä on saanut merkittävän aseman 2010-luvulla.

Diplomityössä on koottu mittaustietoja sekä yleisesti saatavilla olevista lähteistä että pyytämällä yksityisiltä toimijoilta. Yleisesti saatavilla olevia lähteitä edustaa Posivan tutkimukset. Yksityisiä toimijoita ovat kaivokset ja kalliorakentajat. Raporttien tiedot on eritelty ja koostettu tietokantojen käyttämään muotoon. Noin 150 uutta suomalaista jännitystilakoostetta on analysoitu ja valmisteltu uusina tietoriveinä maailmanlaajuiseen tietokantaan. Koosteet ovat valmisteltu noin 1400 erillisestä uudesta mittauksesta, jotka ovat käytettävissä myös uuteen kvantitatiiviseen tietokantaan.

Mittausten monenlaiset epävarmuustekijät ja saatujen mittaustulosten hajonta ovat olleet jännitystilamittauksia haittaavia tekijöitä. Tulosten hajonnan syitä ei aina pystytä selvittämään ja eri syistä epäonnistuneet mittaukset pienentävät tulosten luotettavuutta. Mittausmenetelmien kehittyminen ja laitteistojen parantuminen ovat parantaneet jännitystilamittausten tarkkuutta ja varmuutta ja siten mittausten merkitystä suunnittelussa. Esimerkkinä kehityssuunnasta on LVDT-menetelmän useamman mittauksen ja 3D-mallinnuksen yhdistäminen inversiolaskentaan.

Jännitystilan mittaustavat ja ymmärrys jännitystilasta kehittyvät jatkuvasti. Uusimmat tiedot jännitystilamittauksista auttavat kalliorakentajia sekä kaupunkikohteissa että kaivoksilla ymmärtämään aikaisempaa paremmin jännitystilaa kalliokohteissa.

Avainsanat primääri jännitystila, jännitystilamittaus, hydraulinen murtaminen, irtikairaus, LVDT-menetelmä

Preface

The study started in autumn 2016 and included considerable work to find the measurements. Thank you for all those numerous people and companies who helped to gather the measurements. Especial thanks to Tauno Rautio (Geological Survey of Finland) for providing me about 50 paper folders of measurements for the study. The study has been funded by Aalto University, Finnish Tunneling Association and The Finnish National Group of ISRM.

I would like to thank you my steering group,
• Dr. Juha Antikainen (Aalto University)
• Erik Johansson (Saanio & Riekkola Oy)
• Dr. Jussi Mattila (Posiva Oy)
• Prof. Mikael Rinne (Aalto University, Supervisor)
• Dr. Topias Siren (Aalto University / Stress Measurement Company, Advisor)
• Prof. Emer. Pekka Särkkä (Concave)
• Marja Uski (Insitute of Seismology, University of Helsinki)

for answers to my questions and all the support. My hearty thanks to my supervisor Professor Mikael Rinne and to my advisor D.Sc. Topias Siren, for encouraging me through the project and especially with the last steps of the study.

Thank you for my family for all the support.

Espoo 29.11.2017

Juha Pennala

Table of Contents

Notations

σ_H	[MPa]	Major horizontal stress
σ_h	[MPa]	Minor horizontal stress
σ_v	[MPa]	Vertical stress
σ_1	[MPa]	Maximum principal stress
σ_2	[MPa]	Intermediate principal stress
σ_3	[MPa]	Minimum principal stress
σ_{ij}	[MPa]	Stress component to ij direction
E	[GPa]	Young's modulus
ν		Poisson's ratio
ρ	[kg/m^3]	Density
γ	[kg/m^3]	Unit weight
k		Ration between horizontal and vertical stress
τ	[MPa]	Shear stress
σ_t	[MPa]	Tensile strength
G	[GPa]	Shear Modulus
T	[°]	Temperature

Abbreviations

2D	Two-dimensional
3D	Three-dimensional
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia’s national science agency
HID-cell	Hollow Inclusion Digital Stress Cell (CSIRO HID -cell)
EDZ	Excavation Damaged Zone
FRSDB	Fennoscandian Rock Stress Data Base
GFZ	German Research Centre for Geosciences in Potsdam
HF	Hydraulic Fracturing
ILP	International Lithosphere Program
LVDT	Linear Variable Differential Transformer
OC	Overcoring
Q-WSM	Quantitative World Stress Map
UCS	Uniaxial Compressive Strength
WSM	World Stress Map
USGS	United States Geological Survey

1 Introduction

The bedrock of Earth's crust is in heterogeneous three-dimensional stress state due to geological processes. Stress state of rock is one of the key rock mechanics factors related to the safety and stability of underground excavations for mining and civil engineering purposes.

1.1 Research questions and structure of the thesis

This thesis collects previously uncollected *in situ* rock stress measurements in Finland compiling and analyzing them. The thesis forms necessary data collection to transfer collected information to open rock stress database. The aim of the study is to update Finnish *in situ* Rock Stress Data in international World Stress Map database and present under development database Quantitative World Stress Map. The thesis does not concentrate on defining the influence of rock stress or how the rock stress should be measured, but to compile new data from rock stress measurements and to add or prepare it to be added to open databases.

In the thesis, chapter 1 introduces some concepts of *in situ* rock stress, the World Stress Map, the new Quantitative World Stress Map, rock type and stress regimes.

Chapter 2 presents the methodology for measuring and qualifying the *in situ* rock stress. In addition, present methods to measure stress state in Finland are described and reasons for changes in measurement methods is discussed.

Chapter 3 presents Finnish *in situ* rock stress measurements focusing on previously uncollected *in situ* rock stress measurements and the estimations of quality of measurement data. The localized significance of individual measurements is discussed.

Chapter 4 reviews collected *in situ* rock stress database update. The thesis presents summaries from compilation. Furthermore, the uncertainties, remarks and the further improvements are presented regarding the thesis.

Finally, in Chapter 5 the results achieved in the study are concluded.

1.2 Compressive stresses in medium

Rock below the surface is subjected to stresses resulting from the weight of the overlying rock mass and from locked in stresses of tectonic forces. The natural pre-excavation state of stress is referred to as *in situ* stress, primary stress state or virgin stress state. This Thesis uses concept *in situ* stress. The stress resulting from man-made activities is described as induced stress or secondary stress state.

In situ stress is disturbed inside excavation disturbed zone (EDZ). EDZ is generally defined as the rock zone beyond the excavation boundary where the physical, mechanical and hydraulic properties of the rock have been significantly affected due to the excavation and redistribution of stresses. (Malmgren 2007)

High *in situ* stress in relation to the rock mass strength cause rock bursting, spalling, buckling, heaving or other ground control problems (Kim & Franklin 1987). *In situ* stress is one of the most important boundary conditions for stress analyses for the design of underground excavations since, in many cases, the rock has exceeded the strength of rock and the resulting instability can have serious consequences on the behaviour of the excavations. For example, more stable stress-strength states are reached if tunnel axes are oriented parallel to the major horizontal in situ stress (Tolppanen *et al.* 1998). The failure of a rock mass around an underground excavation depends on many things besides *in situ* stresses like characteristics of the rock mass, geometry of excavation, water and dynamic loads.

Stress in rock can be measured by theories. Stress is a measure of the intensity of force per unit area:

$$\sigma = \frac{F}{A} \tag{1}$$

where,

F is a force [N]
A is an area [m^2] on which the force acts
σ is a normal stress [N/m^2], normal to the area on which the force acts.

The principal stresses can be assumed to act vertically and horizontally. One component acts vertically and two components horizontally. The horizontal stresses are much more difficult to estimate than the vertical stress. Vertical stress increases in more predictable way than horizontal stresses, because the vertical stress component results from the Earth's gravity field. It increases normally approximately with depth and is assumed to increase with depth due to the weight load of the burden as follows:

$$\sigma_v = \gamma * z \tag{2}$$

where,

σ_v is the vertical stress [N/m^2]
γ is the unit weight of overlying rock [kg/m^3]
z is the depth below surface [m].

For example, at the depth of 1000 m below surface, the weight of the vertical column of rock resting on this element is approximately 2700 kg/m^2 or 27 MPa. See Figure 1 for linear approximation according to this formula with some vertical stress measurements around the world.

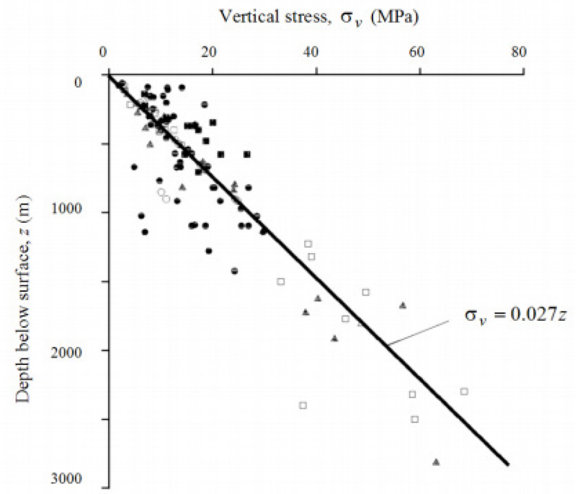

Figure 1. Vertical stress measurements from mining and civil engineering projects around the world. (Brown & Hoek 1978)

Two horizontal stress components are more of tectonic origin and does not increase as predictable as vertical stress. Therefore the horizontal stresses are more complicated to quantify than the vertical stress. The horizontal stress can be estimated using of elastic theory. The total strain can be subtracted to the strain components due to the two perpendicular stresses. The ratio of the average horizontal stress to the vertical stress is estimated to be as follows:

$$\sigma_h = \sigma_v * k = \sigma_v * \frac{\nu}{1-\nu} \tag{3}$$

where,

σ_h is the mean horizontal stress [N/m^2]
σ_v is the vertical stress [N/m^2]
ν is Poisson's ratio
k is $\nu * (1 - \nu)$.

That has proven to be inaccurate as Brown and Hoek (1978) show the ratio tends to be high at shallow depth and that it decreases at depth. The formula to estimate horizontal stress was improved further by Sheorey (1994). His elasto-static thermal stress model of the earth considers curvature of the crust, variation of elastic constants, density and thermal coefficients through the crust and mantle. He estimated to be as follows:

$$k = 0{,}25 + 7 * E * (0{,}001 + \frac{1}{z}) \tag{4}$$

where,

k is ratio σ_h/σ_v
z is depth below surface [m]
E is average deformation modulus, Young's modulus [N/m^2].

Sheorey (1994) revealed that the magnitude of the horizontal stress depends on the elastic modulus, Young's modulus. The model predicts large values of k near surface and a value of 11 MPa at the surface. That is about the same as in an agreement with maximum in situ stress values of about 10 MPa measured at the surface of the Earth.

An outline of Equation 4 is given in Figure 2 for a range of Young's modulus. The curves relating k with depth below surface z are similar to those published by Brown and Hoek (1978) in Figure 3 and others for measured *in situ* stresses. The stress state equal in all directions, $\sigma_v = \sigma_H = \sigma_h$, is referred to as lithostatic stress (Zang & Stephansson 2010).

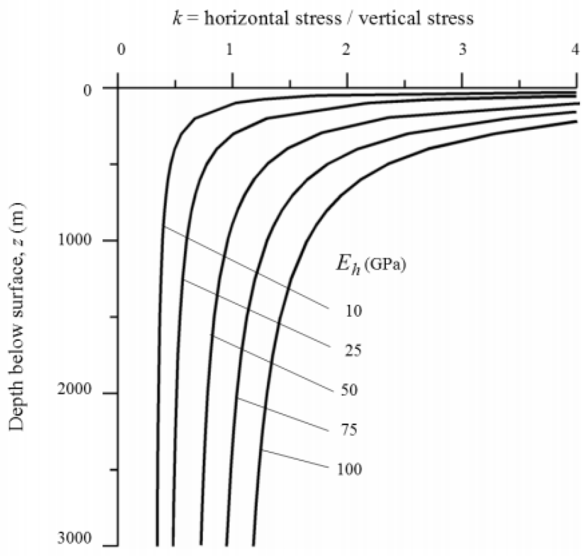

Figure 2. Ratio of horizontal to vertical stress for different Young's modulus (E_h) based upon Sheorey's equation. (Sheorey 1994)

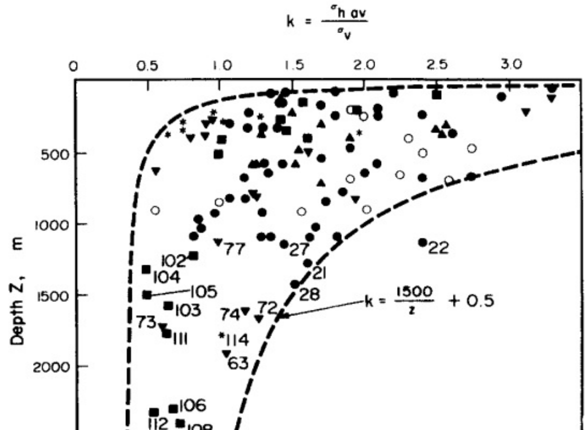

Figure 3. A plot of $k = \sigma_h / \sigma_v$ against depth. (Brown & Hoek 1978)

Poisson's ratio can be defined by the ratio between radial strain and axial strain (Figure 4) as follows:

$$\nu = \frac{\varepsilon_r}{\varepsilon_l} \tag{5}$$

where,

ν is Poisson's ratio
ε_r is radial strain
ε_l is axial strain.

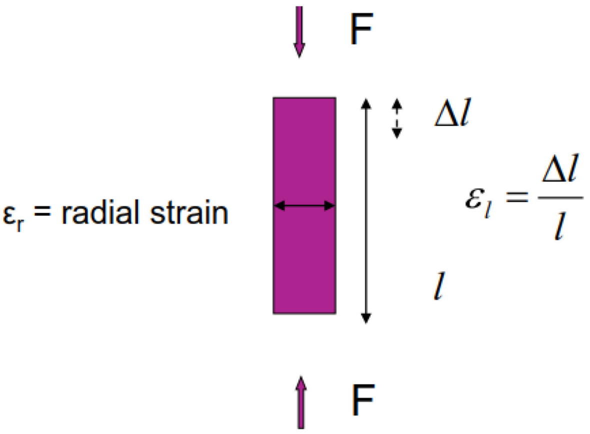

Figure 4. A radial strain and axial strain in uniaxial compression.

Young's modulus describes linear elastic solid material's strain response to uniaxial stress in the direction of stress and can be defined with the one-dimensional Hooke's law connecting axial stress to axial strain as follows:

$$\sigma = E * \varepsilon_l \tag{6}$$

where,

σ is axial stress, normal stress [N/m^2]
E is the Elastic modulus, or Young's modulus [GPa]
ε_l is axial strain [no units].

Material properties E and ν gives an idea of how isotropic the material is. The indirect procedures to estimate the Young's modulus are simple and cost-effective, especially as compared with the *in situ* tests. The *in situ* tests should, however, be used whenever time and means available allow for them. Several investigations point out that the *in situ* Young's modulus (E) is not constant, but depends on the stress conditions, being generally higher in areas subjected to high rock stresses than in rock masses under low stresses. However, this may also be due to better rock mass quality where the higher stress occurs. (Palmström & Singh 2001)

1.3 In situ rock stresses

Local topographic and geological features cannot be taken into account in a large scale models. Local measurements are needed for the local information. Two horizontal stresses are not usually equal. Main horizontal stress is marked as σ_H and minor horizontal stress is marked as σ_h.

The stress state at a point in a rock mass is generally presented in terms of the magnitude and orientation of the principal stresses. The stress state is completely described by six tensor components (Figure 5).

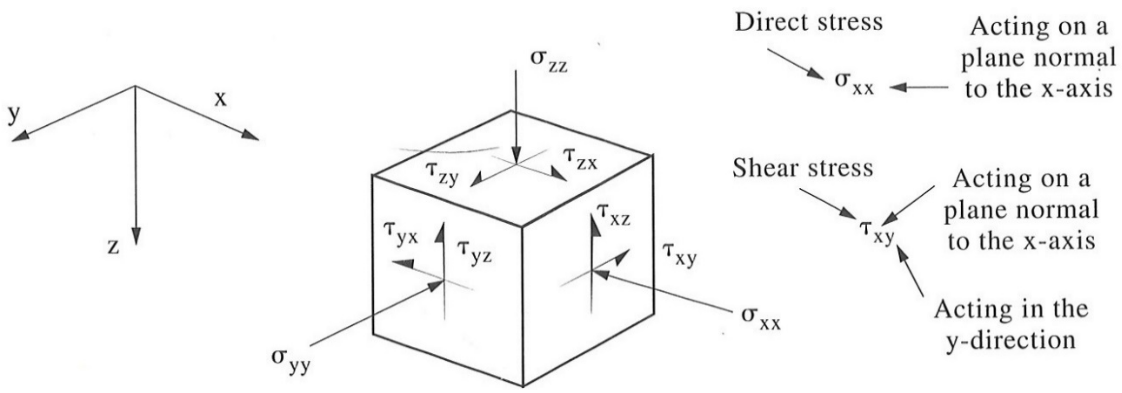

Figure 5. The normal and shear stress components on as infinitesimal cube in the rock aligned with the Cartesian axes (Hudson & Harrison 1997, p.35).

High horizontal stresses are caused by factors relating to erosion, tectonics, rock anisotropy, local effects near discontinuities and scale effects (Hudson, Cornet & Christiansson 2003). Mechanical properties of rock changes over the time. The quality of the rock have an influence to the stability and state of rock.

1.4 World Stress Map

The Fennoscandian Rock Stress Data Base (FRSDB) has been a long-term joint project of Helsinki, Luleå and Trondheim Technical Universities. It was first time initiated in 1986 to provide a collection of rock stresses for Finland, Sweden and Norway. The compilation and program development conducted at the Division of Rock Mechanics in Luleå. That was the first version of FRSDB for stress measurements in the Baltic Shield and the Caledonides. (Stephansson *et al.* 1987).

As a part of the International Lithosphere Program (ILP) the World Stress Map (WSM) project initiated in 1986. The ready-made FRSDB data transferred to the first version of the globally maintained database which was under the leadership of Mary Lou Zoback. The first release of the WSM database was completed in 1992. The main point of interest is the orientation of maximum horizontal stress. The online database provides information on the orientation of global and regional stress fields. Release 1992 included over 4400 of about 7300 *in situ* stress orientations which are considered reliable tectonic stress indicators meaning horizontal stress orientations to be within ±25°. (Zoback 1992)

The total number of data records increased from ~7300 in 1992 over 10,920 in 2000 to 15,969 data records in 2005.

From 1995 to 2008 WSM was a project of the Heidelberg Academy of Sciences and Humanities headed by Karl Fuchs and Friedemann Wenzel. Year 2009 the database was transferred to Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences. Since 2012 the WSM has been a member of the ICSU World Data System.

At this time the WSM is the worldwide data storage for the information of the contemporary crustal stress. The open-access database release 2008 contains 21,750 data records and database release 2016 contains 42,870 data records from different stress indicator types as in Figure 6. (Heidbach *et al.* 2008 ; Heidbach *et al.* 2016)

In year 2016 people in Nordic noticed that it was again time to start a project to update the Fennoscandian Rock Stress Database (FRSDB) with a recent data from Finland. This thesis was established to advance the project. The newest FRSDB-project involves working groups in Finland (Aalto University), Norway (Trondheim NTNU) and Sweden (Luleå LTU). The Institute of Seismology at the University of Helsinki participates the project to manage Finnish focal mechanisms.

In addition to *in situ* stress measurements the WSM data of stress orientations come from three main sources of stress indicators: earthquake focal mechanisms, well bore enlargements or breakouts, and geological data on young volcanic vent alignments and fault offsets. (Heidbach et al. 2008)

The World Stress Map includes a quality ranking scheme based on the number, the accuracy and the depth. The ranking scheme was introduced by Zoback and Zoback (1991 and 1989) and refined and extended by Sperner *et al.* (2003) and Heidbach *et al.* (2010). The World Stress Map release 2008 presents newest revised and extended quality ranking scheme version.

Each WSM data record is assigned a quality between A and E, with A being the highest quality and E the lowest. A-, B- and C-quality data is considered reliable for the use in analysing stress patterns and the interpretation of geodynamic processes. (Heidbach *et al.* 2016).

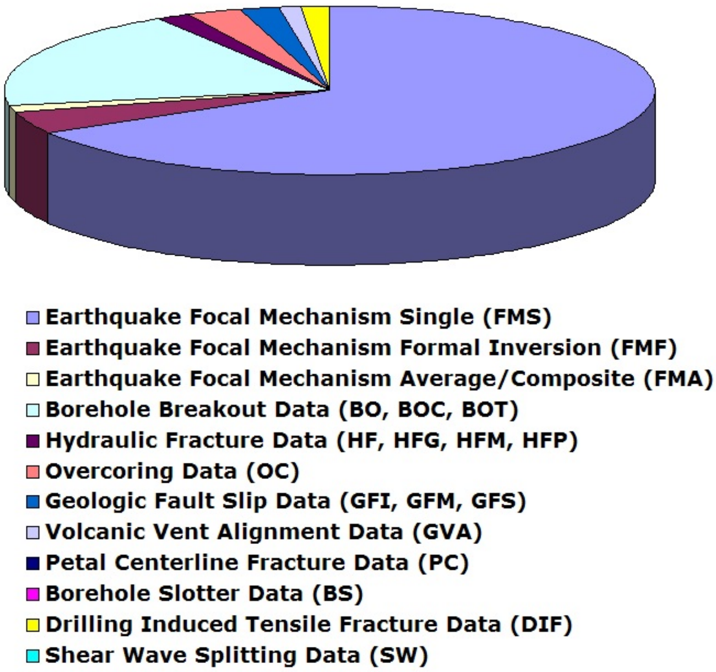

Figure 6. Pie chart showing stress indicators types in WSM release 2008. (Heidbach et al. 2008).

1.5 Quantitative World Stress Map

The Quantitative World Stress Map (Q-WSM) database is the new development step in an evolution of open worldwide rock stress database. It is an entirely new database. In Figure 7 is presented a prototype input template, which has been introduced by Zang *et al.* (2012).

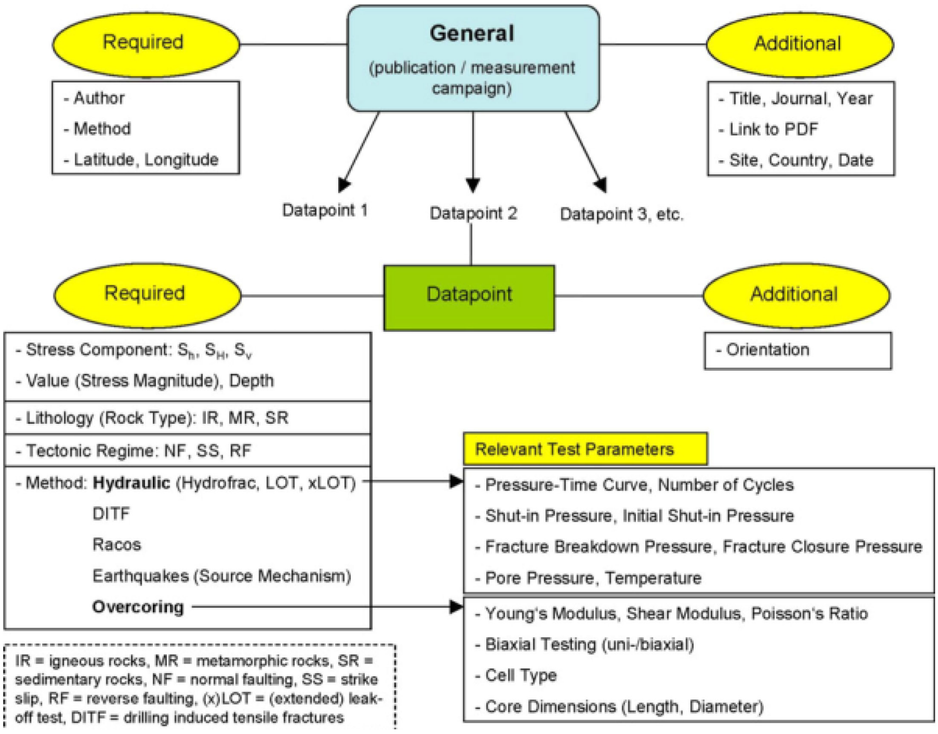

Figure 7. *Metadata and prototype input template in Quantitative World Stress Map (Q-WSM) (Zang et al. 2012).*

This new prototype database is being created based on year 2011 version of the Stephansson and Zang project (Zang *et al.* 2012). The Quantitative World Stress Map database structure is at present being revised. At the moment thesis is waiting more information about the situation of the database and data is being prepared as a year 2011 draft version of the database.

The Quantitative Stress Field database focus on rock-type specific stress magnitudes versus depth. This allows to investigate the vertical stress component for different lithology. With enough measurement information about depth and lithology, it is possible to display new kinds of tables of stress magnitudes in 2D and 3D stress space and to investigate stress ratios in relation to depth and lithology as in Figure 8. (Zang *et al.* 2012)

The Quantitative World Stress Map database compiles rock-type specific stress magnitudes versus depth (Zang *et al.* 2012). Together with the σ_H orientation in WSM database, the stress magnitudes in the new database become a more quantitative tool to describe stresses in the Earth's crust. Particular for rock mechanics and rock engineering applications, the Q-WSM will become a useful source of information to get information about rock stress at area or region. (Zang *et al.* 2012)

The development of rock stress database towards Q-WSM increases need to improve methods to measure rock stress and to get more measurements deeper than at the very surface of crust. Also collected information have to do more accurately geologically.

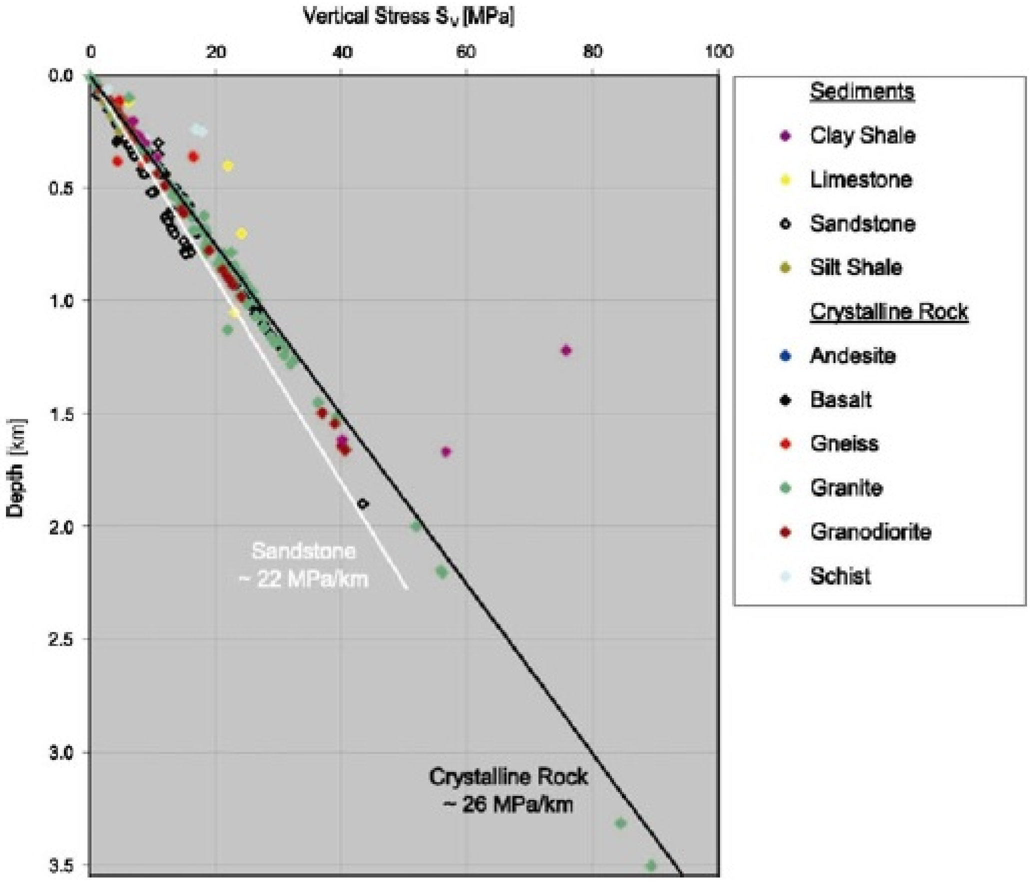

Figure 8. *Lithologic stress magnitudes versus depth for the vertical stress component (Zang et al. 2012).*

1.6 Rock type

The new Q-WSM includes an information about rock type as an important feature. The bedrock of Finland belongs to a Precambrian North European and East European bedrock area, East European Craton, which is one of the oldest parts of the Eurasia. The Precambrian bedrock area is exposed in Fennoscandia and Ukraine. The exposed geologic province in Fennoscandia is known as a of the Fennoscandian shield. The majority of non-Fennoscandian East European Craton is covered with sediment rocks (see Figure 9).

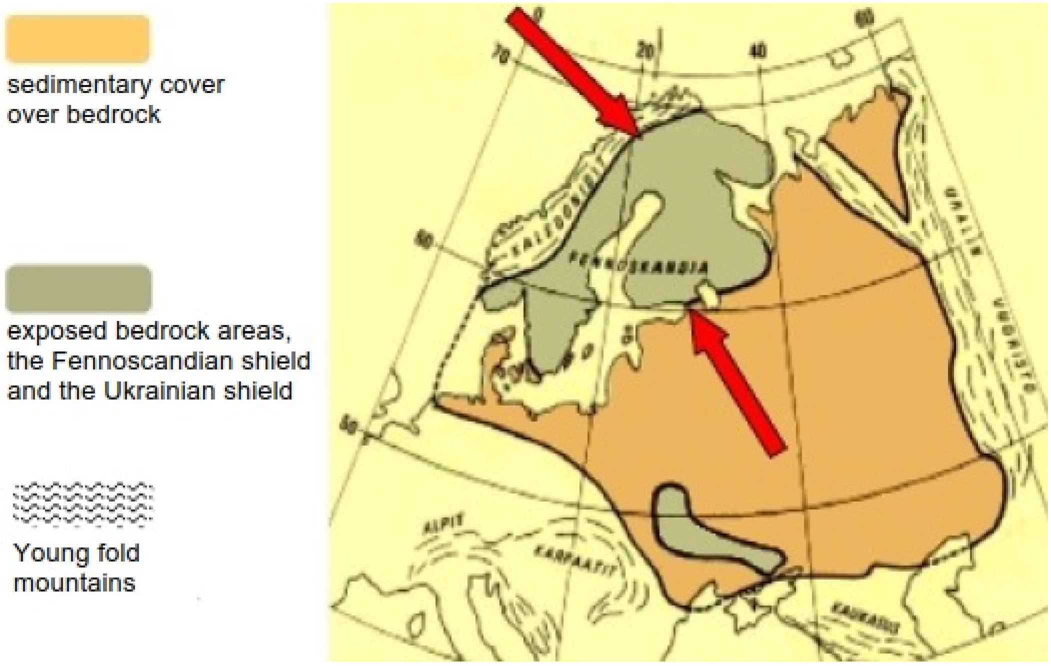

Figure 9. Fennoscandia shield as a part of East European Craton. Modified from (Geologia.fi 2017).

Finnish rocks consists of Precambrian crystalline igneous and high-grade metamorphic rocks. The rock of Finland consists of silicate-rich (felsic to intermediate) intrusive igneous rocks like granite, granodiorite and diorite (52%), mixtures of metamorphic rocks and igneous rocks like migmatites (22%), schists, a medium-grade metamorphic rocks, like phyllite, mica schist and mica gneiss (9%), silica-poor (mafic to ultramafic) igneous rocks like gabbro, diabase and amphibolite (8%), quartzite and sandstone (4%), granulites (4%) and Southern Finland limestone (0,1%) (Lehtinen, Nurmi & Rämö 2005). From (Nironen 2017) can be seen newest general information about the bedrock of Finland. For example about the plutonic rocks of the Central Finland granitoid complex in which quartz diorites, granodiorites and granites dominate form a continuous series grading from gabbros into granites. (see Figure 10)

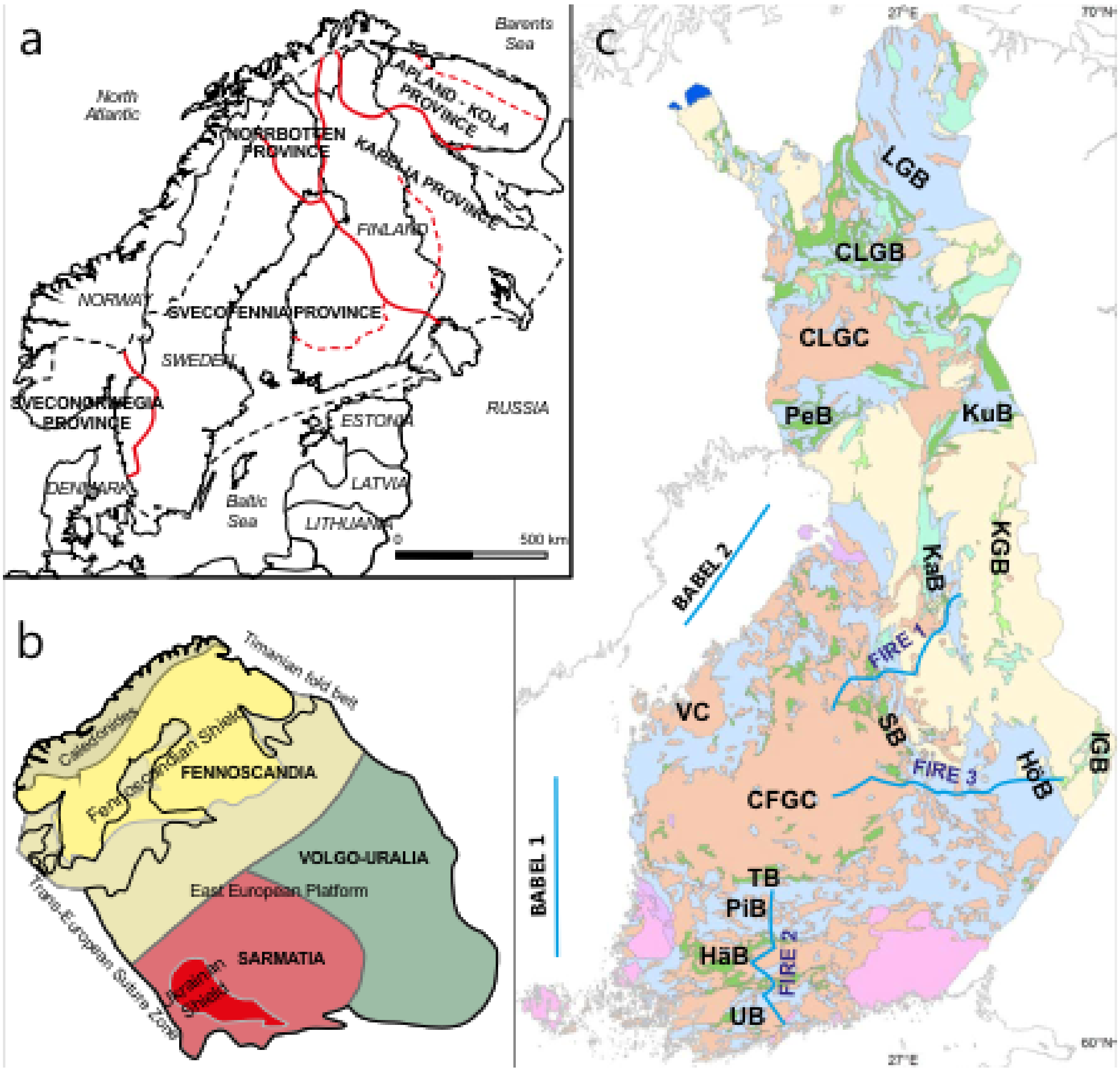

Figure 10. a) Tectonic provinces in the Fennoscandian Shield. Province boundaries are shown by solid red line, subprovince boundaries by broken red line. b) The East European Craton (Baltica) with crustal segments Fennoscandia, Sarmatia and Volgo-Uralia. c) Generalized bedrock map of Finland. The locations of BABEL 1 and 2 deep seismic reflection profiles, and sections of FIRE 1, FIRE 2 and FIRE 3 profiles are shown by blue lines. LGB = Lapland granulite belt, CLGB = Central Lapland greenstone belt, CLGC = Central Lapland granitoid complex, PeB = Peräpohja belt, KuB = Kuusamo belt, KGB = Kuhmo greenstone belt, KaB = Kainuu belt, SB = Savo belt, IGB = Ilomantsi greestone belt, HöB = Höytiäinen belt, VC = Vaasa complex, CFGC = Central Finland granitoid complex, TB = Tampere belt, PiB = Pirkanmaa belt, HäB = Häme belt, UB = Uusimaa belt. (Nironen 2017)

Theories present usually a presumption about isotropic, homogenous and linear-elastically behaving rock. That is not the actual situation. In general, rocks are anisotropic although not as anisotropic as wood or composite materials. Relative to stress measurements, anisotropic rock including a lot of faults is not favourable (Hakala, Tolppanen & Ojala 2005).

1.7 Stress regime

Originally Anderson (1951) developed a system about stress regimes. Knowledge of the *in situ* stress regimes provides perception into the feasibility of crustal dynamics such as plate tectonics, seismic risk evaluation and earthquake prediction.

The stress magnitudes are defined using the standard geologic/geophysical notation with compressive stress positive and S1>S2>S3, so that S1 is the maximum and S3 the minimum principal compressive stress. The standard categories of stress regimes are normal faulting (NF), in Figure 13, thrust faulting (TF), in Figure 11, and strike-slip faulting (SS), in Figure 12 (Heidbach et al. 2016). In Finland the most typical stress regime is a thrust faulting where the main horizontal stress magnitude is the greatest of possible three stress components (Vuorimiesyhdistys 1981).

In Finland main horizontal stress is 2.5-fold in comparison to vertical stress (Lappalainen 1981; Tolppanen & Johansson 1996). The stress state equivalent to depth of 200 m can be already at the depths of ten to twenty m (Stephansson *et al.* 1986, pp 21-32.). High horizontal stress state in Finland comes from geological origins. Mid-Atlantic ridge and Alpine margin create a horizontal stress in a direction from North-West to South-East.

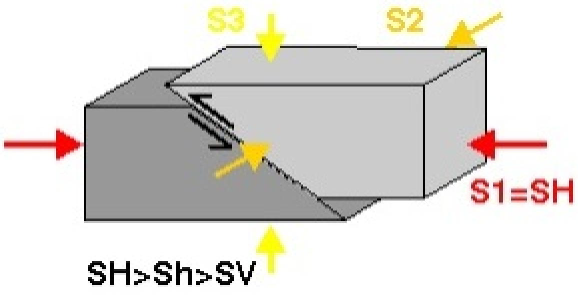

Figure 11. A thrust faulting (TF) stress regime. (Heidbach et al. 2016)

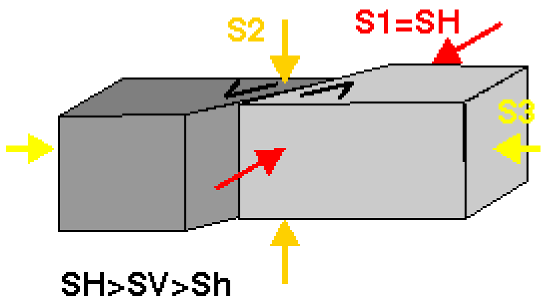

Figure 12. A Strike-slip faulting (SS stress regime). (Heidbach et al. 2016)

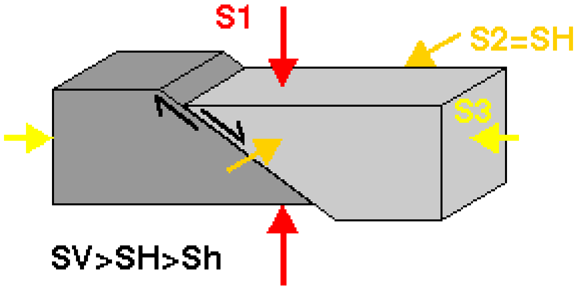

Figure 13. A normal faulting (NF) stress regime. (Heidbach et al. 2016)

2 Rock stress measurement methods

The most techniques to measure *in situ* stress for rock mass use methods to disturb the rock and measure the response. Those responses, which can be something like strains, displacements or required breakdown forces, are then analysed based on assumptions of rock's constitutive behaviour and its geological and structural properties. (Hakala, Tolppanen & Ojala. 2005)

2.1 Measurement methods in Finland

In situ measurement methods in Finland are hydraulic fracturing (HF), overcoring (OC) and new LVDT method, which is categorized to overcoring group in WSM. Old overcoring methods Hast and Leeman (Tolppanen & Johansson 1996) have not been used during last twenty years. Overcoring method Borre was last used in 2000 in Salmisaari (Mononen 2000b). Only old overcoring method, which is yet in use, is the method using CHIRO HI/HID cell as Varis & Kivinen (2014).

Because there is no direct stress measurements, only the effect can be measured. Rock stresses in good rock quality is possible to determine with an error of 10-20% in magnitude and 10-20 degrees in orientation. The most used measurement methods in Finland at present are hydraulic fracturing and LVDT method. LVDT method uses LVDT cell together with inversion-based calculations. Because of quality standards, not all measurements are counted as reliable data records for databases. Older overcoring methods like triaxial cells are used only seldom during last ten years. Hydraulic fracturing has been in use in Finland already from year 1990 and continues to be in use. New LVDT method has been in intensive testing and at present it is the most accurate method to use in most cases and usually the only possible method in sidecoring situations in Finland (Hakala *et al. 2012*).

2.2 Hydraulic fracturing

Last twenty years hydraulic fracturing has been the most important method to determine rock stress in Finland. Hayashi & Haimson, (1991) have said hydraulic fracturing to be the bestknown method for determining *in situ* stress in the subsurface. Because the minimum principal stress in Finland is in most cases close to vertical, measurements is conducted in vertical boreholes to get horizontal minor and major stresses. The instantaneous stress release technique hydraulic fracturing uses water pressure to measure rock stress. Water pressure causes rock failure in closed section in borehole. The test section is selected on the grounds of not having fractures before measurement. That is done by picking sections from core samples. Usually the idea is to measure several sections in one borehole. In the material of Thesis usual tendency has been to find at least 10 measurable sections in every borehole. The most common reason to fail measurement is a fracture or fractures in rock in the direction of measurement before the measurement. A reliable result is only possible in an intact rock. The direction of breakage of measurement is perpendicular to the minor horizontal stress direction in rock. Minor and major horizontal stresses are calculated based of water pressures in measurement.

Hydraulic fracturing uses four main presumptions. The first presumption is that the rock is isotropic, homogenous and behaves linear-elastically. The second presumption is that one of the main stresses is parallel to borehole axis. The third presumption is that vertical stress comes from gravitational compression. The fourth presumption is that the pore water pressure is zero.

Suomen Malmi Oy has been the biggest hydraulic fracturing contractor in Finland at least during last thirty years. Hydraulic fracturing equipment used by Suomen Malmi Oy has been Minifrac System manufactured by Mindata Australia Ltd. It is possible to get results both analogically and digitally. If needed, analogical results are digitized. Mainly digitized results have been used during last 15 years.

The system has different equipment for breaking and for taking crack impression record for directions (Figure 14). A breaking section is 15-16 cm long section between rubber packer system (upper in Figure 15). The equipment for taking crack impression record is 40 or 65 cm long (lower in Figure 15). It illustrates test section of 15-16 cm and an area of rubber packers of 25 or 45 cm. The diameter of borehole is usually either 38 mm or 46 mm. The diameter of both equipments is about 44 mm. System has two separate highpressure pumps. Both breaking area and packer area has different pumps. The system can produce independent maximum pressure of 35 MPa to both areas. A maximum stream velocity is 200 ml / min. The pressure was first observed by analogical recorder and digitized for calculations. Pressure changes were earlier plotted to paper but later digitally saved to SD-memorycard. The sampling frequency is about 9 kHz in 20 kPa resolution.

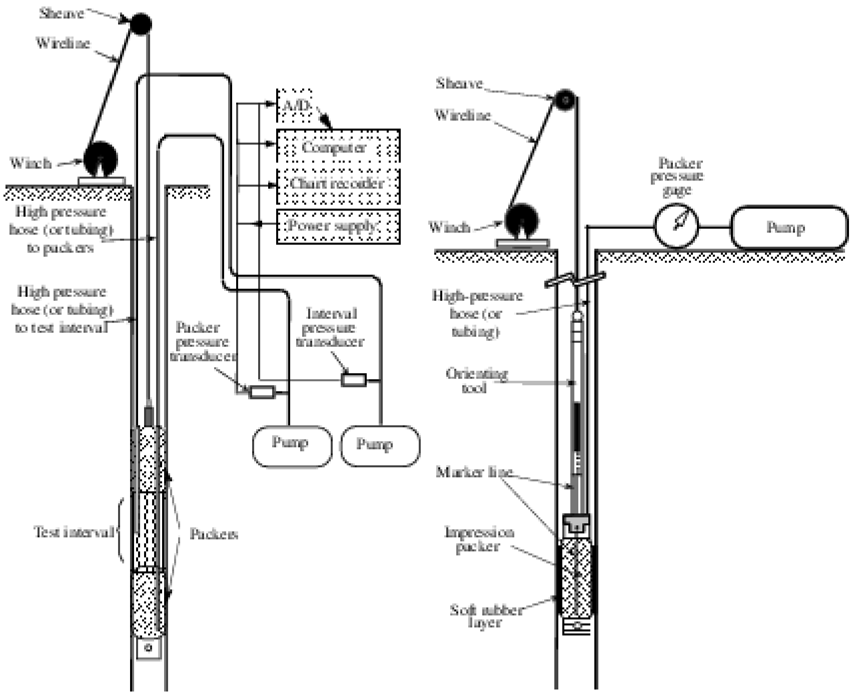

Figure 14. Minifrac system equipment used for breaking (left) and for taking crack impression record for directions (right). (Haimson & Cornet 2003).

Figure 15. Minifrac system equipment for breaking (upper) and for taking crack impression record for directions (lower). Recording equipment uses mechanical chart recorder. (Majapuro 2003c)

As an example of using Minifrac System for hydraulic fracturing to measure stress is a case from Majapuro (2003c) for Kluuvi electrical station. Mindata Australia Pty. Ltd.'s Minifrac system has been used to produce fractures to borehole. Those fractures transfer as a picture to rubber when the rubber band has been pressed about 20 minutes against borehole wall. The system produces a field data sheet, crack impression record. That picture to the rubber can be seen for depth of 13,25 and 13,75 m in Figure 16 and at the depth of 14,25 and 17,10 m in Figure 17. From that test section graph can be taken an estimate from two horizontal directions. Estimates of those two directions are at the depth of 13,25 m 300 degrees and 150 degrees (Figure 16) and at the depth of 13,75 m 320 degrees and 180 degrees (Figure).at the depth of 14,25 m 325 degrees and 190 degrees (Figure 17) and at the depth of 17,10 m 10 degrees and 150 degrees (Figure 17). If two horizontal directions are not opposite from each others inside 15% range, the measurement is not inside first quality rank. The second quality rank can be ranked if two horizontal directions are opposite from each others inside 30% range.

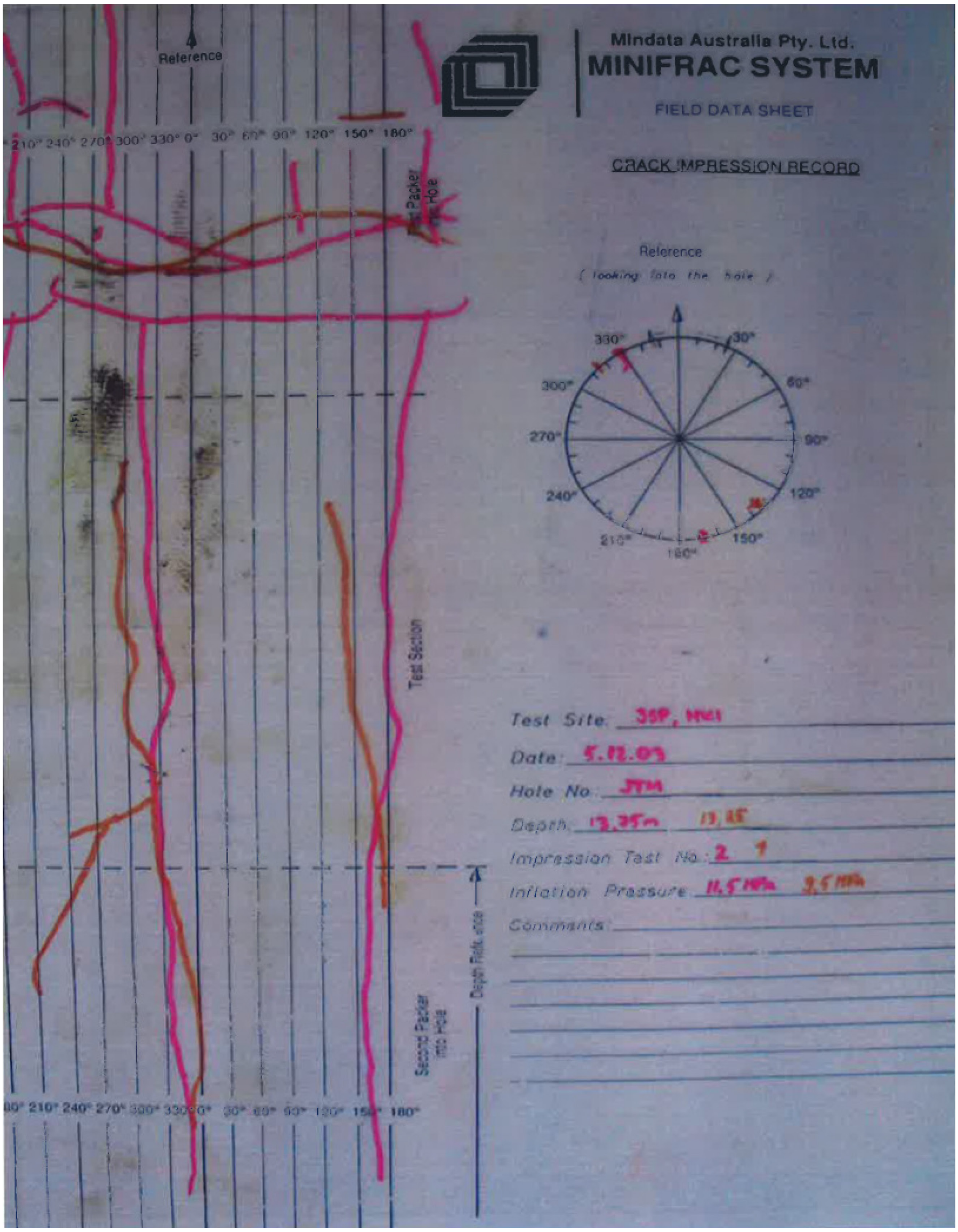

Figure 16. Minifrac system field data sheet crack impression record for 13,25 m with chosen directions of 300 degrees and 150 degrees, and 13,75 m with chosen directions of 320 degrees and 180 degrees. (Majapuro 2003c)

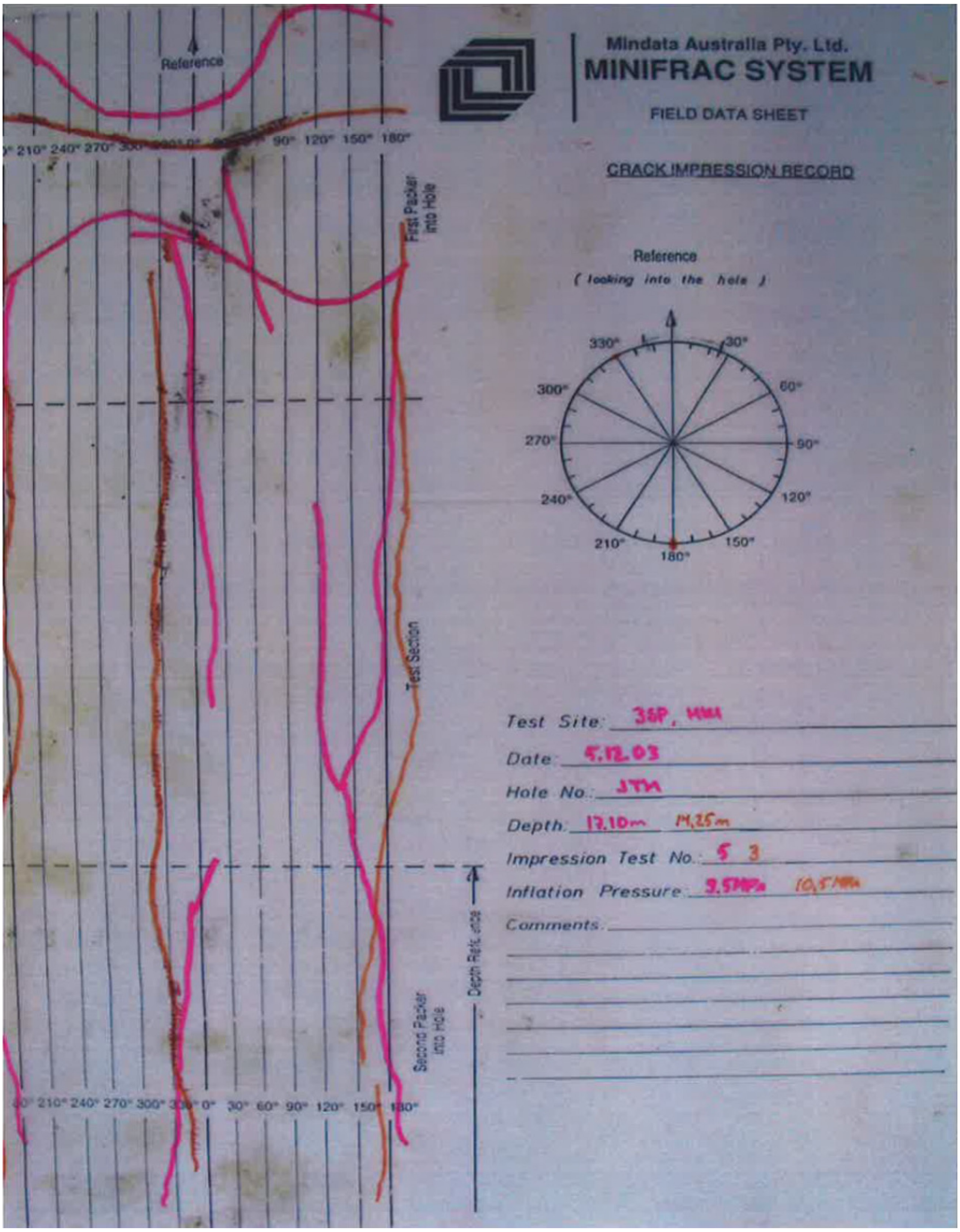

*Figure 17. Minifrac system field data sheet crack impression record for 14.25 m with chosen directions of 325 degrees and 190 degrees, and 17.10 m with chosen directions of 10 degrees and 150 degrees. (*Majapuro 2003c).

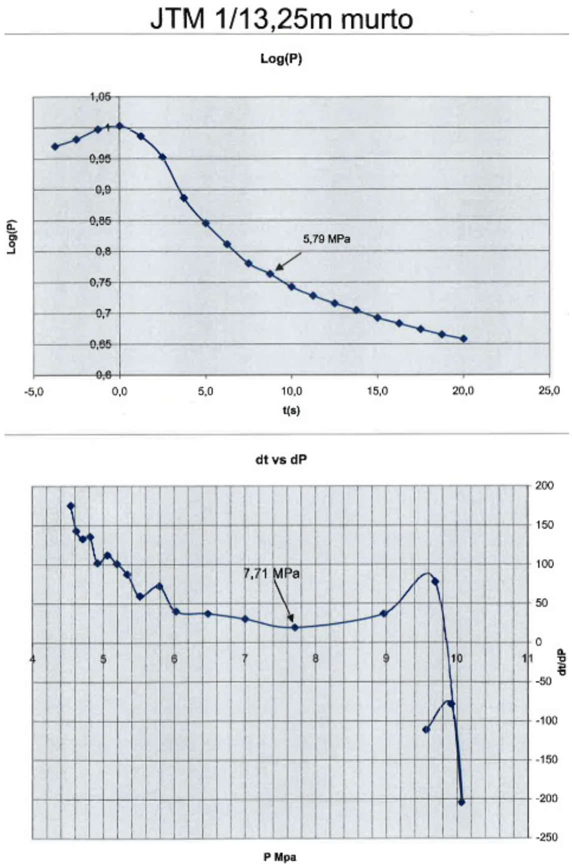

*Figure 18. Graphs to determine shut-in pressure (Ps0) in 13.25 m. (*Majapuro 2003c).

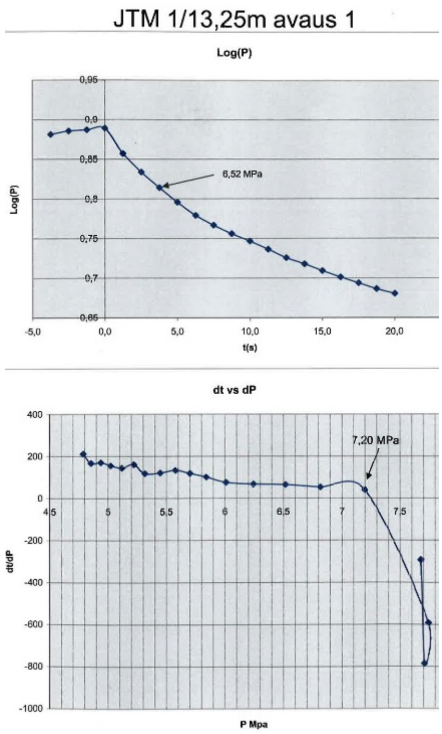

*Figure 19. Graphs to determine second shut-in pressure (Ps1) in 13.25 m. (*Majapuro 2003c).

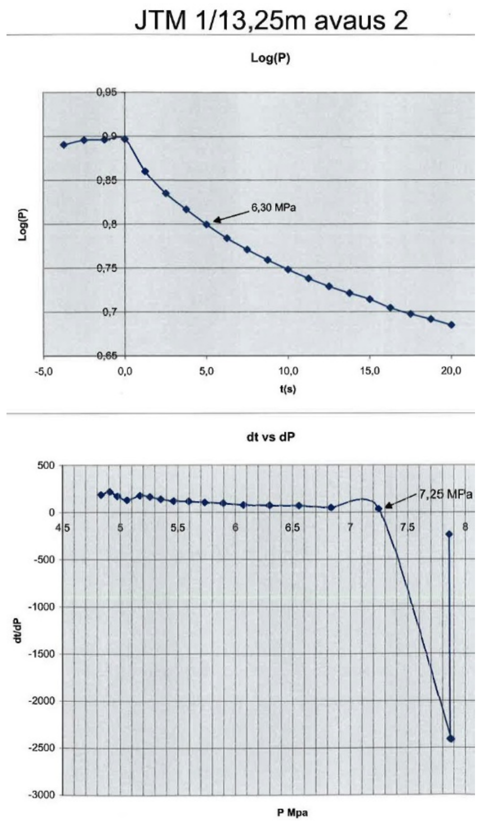

*Figure 20. Graphs to determine third shut-in pressure (Ps2) in 13.25 m. (*Majapuro 2003c).

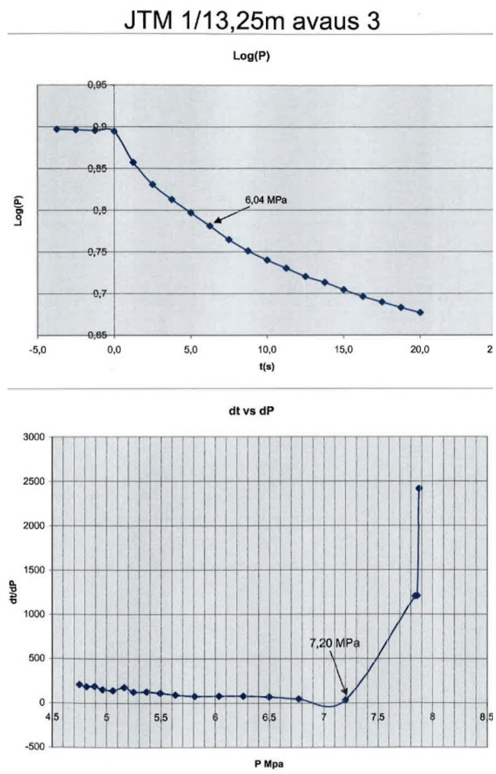

*Figure 21. Graphs to determine fourth shut-in pressure (Ps4) in 13.25 m. (*Majapuro 2003c).

Table 1. An example of measurements of hole JMT in Helsinki city center.

Location	Hole	Depth	SigH	Sigh	SigH	Sigh	Method	
		metre	MPa	MPa	degree	degree		
ALEKSANTERINKATU	JTM	14,7	4,05	2,59	300	150	Log(P)	
"	"	19,3	7,53	4,22	300	150	dt/dP vs P	
"	"	21,8	6,08	3,66	320	180	Log(P)	
"	"	24,5	9,41	4,83	320	180	dt/dP vs P	
"	"	26,3	11,14	5,84	325	190	Log(P)	
"	"	28,5	6,21	3,62	325	190	dt/dP vs P	
"	"	29,5	4,09	2,60	10	150	Log(P)	
"	"	26,3	11,14	5,84	10	150	dt/dP vs P	

Graph curves are used to determine pressure values. There are two techniques to determine shut-in pressure (Ps). Log(P) technique is used to determine shut-in pressure (Ps0 from Figure 18, Ps1 from Figure 19 Ps2 from Figure 20 and Ps3 from Figure 21). The lowest shut-in pressure is determined from the part of curve where the pressure is constant. Technique DT/dP versus P gives the biggest possible shut-in pressure (Ps0 from Figure 18, Ps1 from Figure 19, Ps2 from Figure 20 and Ps3 from Figure 21).

Minor horizontal stress (σ_h) comes from the average shut-in pressure:

$$\sigma h = \left(\frac{Ps1 + Ps2 + Ps3}{3}\right) \tag{7}$$

where,

σ_h is minor horizontal stress [N/m^2]
Ps1 is the first shut-in pressure [N/m^2]
Ps2 is the second shut-in pressure [N/m^2]
Ps3 is the third shut-in pressure [N/m^2]

The reopening pressure (Pr) comes graphically from the change of slope. Pr_1 is the first reopening pressure, Pr_2 the second reopening pressure and Pr_3 the third reopening pressure. Third reopening is done if needed or if second reopening is not clear. (Amadei & Stephansson 1997).

The major horizontal stress (σ_H) can be calculated from shut-in pressure and average reopening pressure:

$$\sigma H = 3 * Ps - \left(\frac{Pr1 + Pr2 + Pr3}{3}\right) \tag{8}$$

where,

σ_H is major horizontal stress [N/m^2]
Pr1 is the first reopening pressure [N/m^2]
Pr2 is the second reopening pressure [N/m^2]

Pr3 is the third reopening pressure [N/m^2].

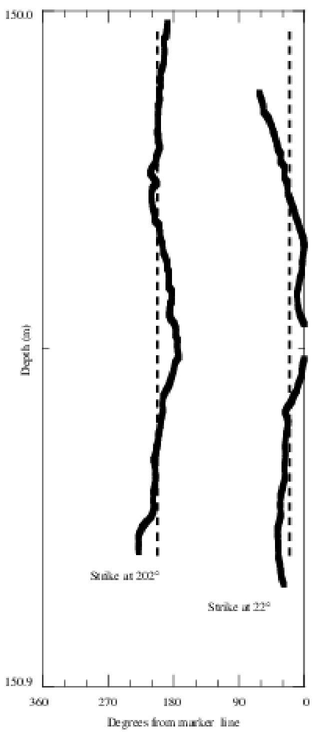

Figure 22. Successful orientation determination. (Haimson & Cornet 2003).

Suomen Malmi Oy assesses / estimates two factors from measurements. The scale of the quality assessment of the measurements uses four classes. The pressure graph / curve (Figure 22) is determined in four steps:

1. Pressure before the test is stable, creases are clear, curve is consistent.
2. Pressure before the test is stable, creases are unclear, curve has deviations.
3. It is not possible to get clear creases from curve or curve has large deviations.
4. Unsuccessful measurement.

Fracture direction is determined in four steps:

1. Fractures opposite ±15°, vertical and upright.
2. Fractures opposite ±30°, almost vertical, possible breaks.
3. Fractures not opposite, several fractures formed.
4. Horizontal fracture.

2.3 Overcoring

Overcoring stress relief methods rely on an elastic response of the rock mass observed with an instrument overcored from installed place in a borehole. The *in situ* stress is determined based on strains in the wall around the instrument in the hole. Overcoring technique can use different types of cells developed for the purpose. The most used cell-type is a triaxial probe allowing the derivation of the state of stress sensors in three-dimension from one successful measurement like CSIR- or CSIRO -type cell (Figure 23) with 9 or 12 strain gauges. Other example of triaxial cell is a Borre Probe whose measurement procedure can be seen in Figure 24. LVDT is the newest overcoring method used in Finland. It uses multiple connectable measurements and calculations based 3D modelling. It has similarities with measurement methods like USBM, which is not explained here, because it is not used in Finland. The LVDT is described separately in the next Chapter.

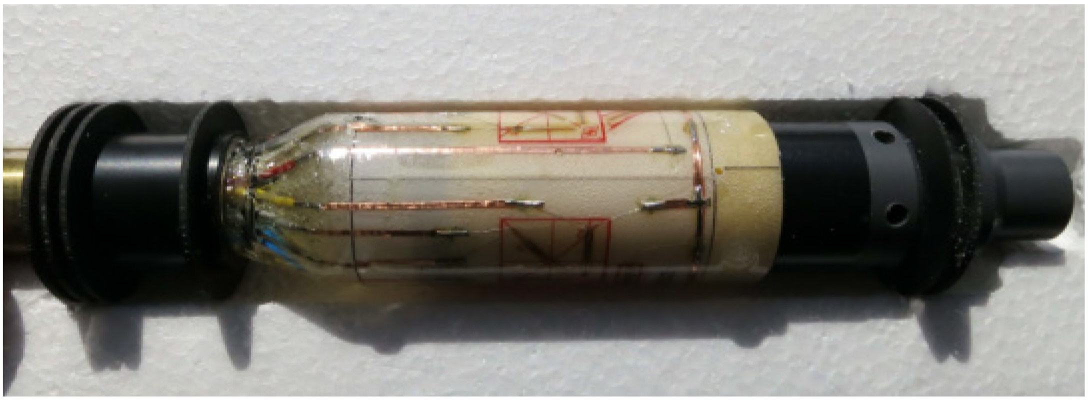

Figure 23. CSIRO HI –cell by ES&S (Majapuro 2005).

Hakala (2006) has pointed out some problems of *in situ* overcoring stress measurement. Even one degrees change in core temperature can have significant effect as inaccuracies in measurement of coring advance accuracy, which should be ±1 mm. Different problems with glue are commonly problematic as well as problems with strain monitoring and biaxial tests. (Hakala 2006)

Transient strain behaviour during overcoring has been a problem in a quality of overcoring method. Hakala (2006) has developed a computer program which can simulate those problematic transient strains. The program is possible to be modified for different overcoring probes. It is possible to recalculate the *in situ* rock stress based earlier transient or final strain values. The numerical error of developed program was found to be less than 5%. Although the solution is very sensitive for measured strains and coring advance, on the grounds of case studies the developed method improves the reliability of stress measurement data. (Hakala 2006)

Triaxial cell CSIRO HI/HID, made of epoxy, is an Australian cell to measure transformations in rock. It has been developed and used first time in the 1970s. The outer diameter of cell is 36 mm and the inner diametre is 32 mm (Figure 23). The cell has 12 stretch slips planted to the depth of 0,5 mm from epoxy tubes exterior and the sensor to measure temperature. Two from stretch slips is located parallel to axis of cell, five tangential to axis and five to other directions between parallel and tangential axis. Transformation is measured during overcorinf and afterwards. Transformations is changed to stresses with the help of Hooke’s law. (Tarvainen 2008)

Overcoring is started drilling 116/93 mm investigation hole. On the bottom of the hole is drilled 38/22 mm pilot hole. The advisable length of pilot hole is at least 50 cm. The pilot hole is cleaned with care and the cell is glued to the position. The cell has to be located sufficient far away from the bottom of the pilot hole and bigger hole in unbroken rock. The glue dries over 32 hours. The overcoring can be started when the glue is dry. The rinsing water is 0 – 3 degrees Celsius colder than rock to prevent the cell to warm. After overcoring have to wait some time to settle down moving of stretch slips. Biaxial cell measurement is accomplished pressing core sample using pressure series of 0-2,5-5-7,5-

5-2,5-0 or 1-2-3-4-5-4-3-2-1 MPa to measure Young's moduli (E) and Poisson (υ) number. If on the grounds of biaxial testing transformation is linear, it is possible to calculate *in situ* stress state on the grounds of stretch values (ending value – beginning value).

If the borehole is oriented in y direction and the xz-plane is perpendicular to the borehole, the diametrical deformation Δd at θ can be represented based on the theory of elasticity and the Kirsch solution.

Swedpower AB has developed a Borre measurement cell for overcoring. The Borre Probe is a triaxial strainmeasuring instrument. Borre measurement cell mounting and measurement procedure is shown in Figure 24. The diameter of hole is 76 mm (1) and the diameter of pilot hole is 36 mm (2). The Borre Probe go down in installation tool (3) and releases from installation tool to the pilot hole (4). Gaiges bond to wall under pressure from the nose cone. The installation tool is pulled out (5) and the Borre Probe is overcored and recovered in core baller (6).

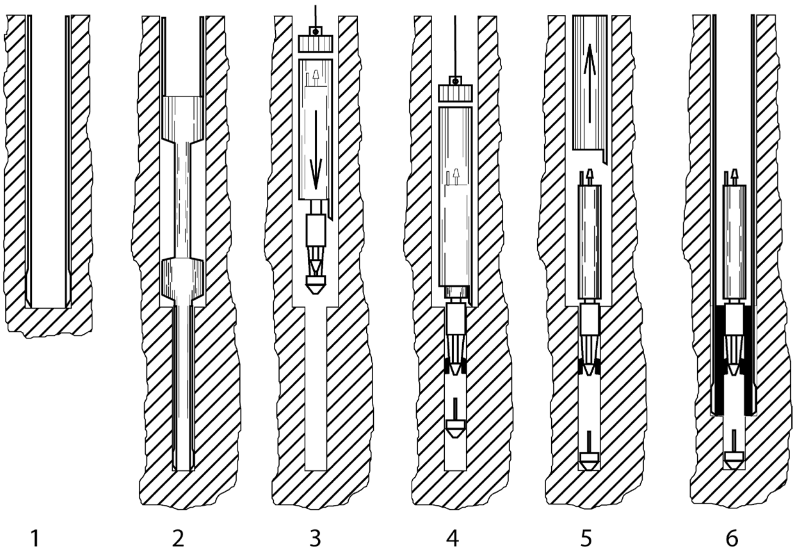

Figure 24. The procedure for a single stress measurement using the Borre probe (Sjöberg, Christiansson & Hudson 2003).

Last triaxial cell used in Finland has been CSIRO HI/HID cell in 2014 (Varis & Kivinen 2014). In CSIRO HI/HID cell the strains are no longer on the borehole surface but are embedded into the hollow epoxy. The cells have usually diameters of 36 mm to 46 mm. The glue is located on top of cell and is usually about 2 mm thick. The strain gages are located 1,5 mm away from the borehole wall. The arrangement of strain gages gives three circumferential strain measurements, two axial strain measurements and four additional strain measurements. (Amadei & Stephansson 1997).

2.4 LVDT cell

Hakala (2006) has pointed the key matters to good quality *in situ* overcoring stress measurement. The LVDT can be seen as a result from those outlinings. Improving the quality of preparation, measuring and interpretation work is a ongoing target in all measuring, but improving the probe is also a good way to take steps forward. The LVDT Probe leaves problems with glue out of questions. The LVDT takes advance putting new technical evolution into operation in computational inverse calculation and using photogrammetric technology.

The diameter of cell is bigger than many earlier cells with 138 mm diameter and with a 200 mm overcoring diameter.

Measurements include large uncertainties because of rock heterogeneity but also because of problems in measurements like especially with glues in overcoring methods. The new measurement method called LVDT based structure without glue started to be planned during year 2009.

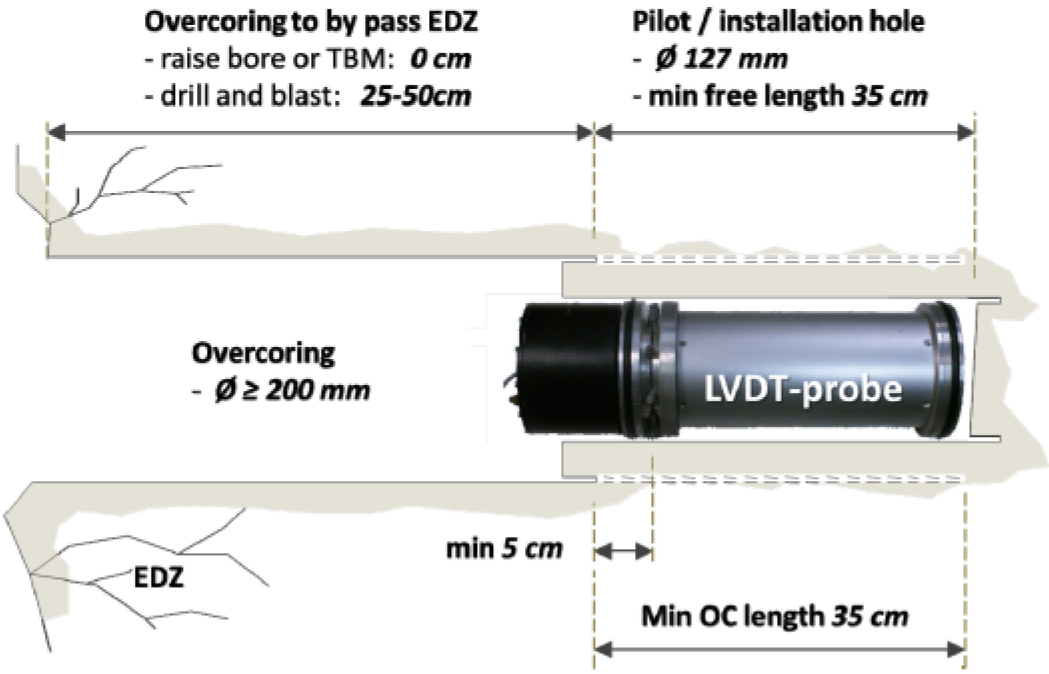

*Figure 25. Suggested drilling and installation depths (*Hakala *et al.* 2013).

Matti Hakala created LVDT-cell method ten years ago to measure secondary or induced stresses in the vicinity of an excavated surface. It has been developed to overcome problems encountered with traditional overcoring methods. It utilizes the overcoring methodology, measuring the radial convergence using usually three to five measurements around the three-dimensional tunnel section. The large measurement hole diameter minimizes the vulnerability regarding heterogeneity. A mechanical mounting system eliminates glue related problems such as drifting and long curing times. LVDT uses best fit inverse solution between measured and simulated convergences and requires numerical techniques using a focused iterative search. It uses a 127-mm diameter pilot-hole and the overcore diameter of 200-mm or greater. The minimum overcoring length is only 350mm. (Hakala *et al. 2012)*

Solution method does not require full stress release, because solution uses displacement differences between the phases before and after coring. Side coring can be used to prevent ring disking. LVDT-Cell (Figure 26) has been tested and calibrated in Äspö Hard rock laboratory in Sweden. Testing has been done in wellknown stress state about 450 m under see level. This study suggests that in case of a drill-and-blast tunnel the minimum measurement depth for establishing the state of stress should be approximately 50 cm. (Hakala *et al. 2012)*

If normally used overcoring cannot be done, sidecoring measurements can usually be done instead. LVDT-method has raised the quality of overcoring. Clear advantages of the methodology are the capability to manage with short boreholes and a compact drill rig, and avoiding the issues associated with gluing and the time needed for curing.

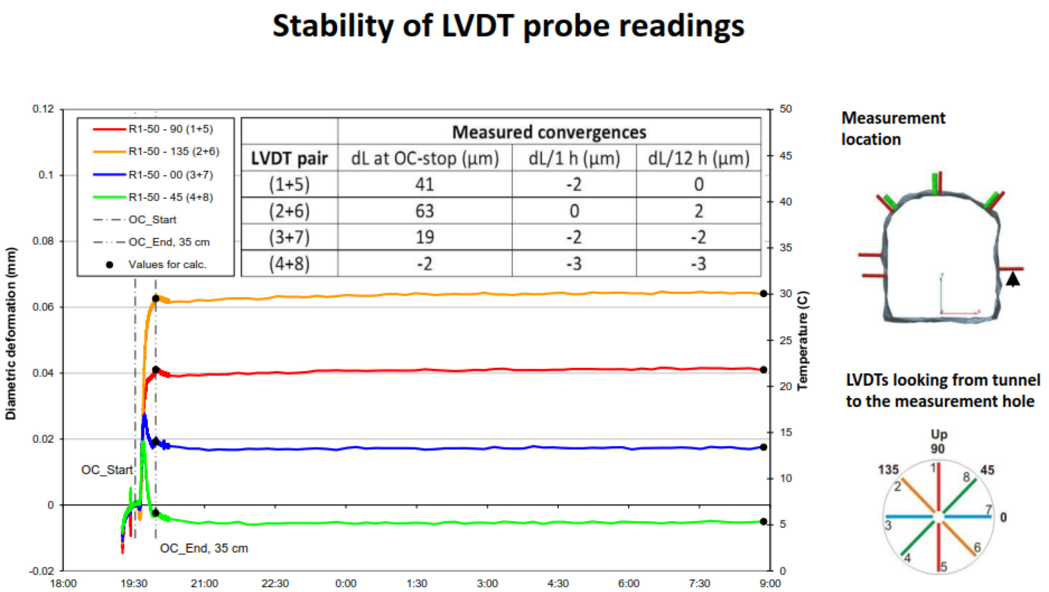

*Figure 26. An example of LVDT probe readings and a picture of measurement location (*Hakala *et al.* 2012).

2.5 Quality ranking

The quality of data records is estimated for WSM. Dispersion of stress directions in measurements can be significant and thus problematic inflicting low quality data records. The quality of data is analyzed and interpreted for WSM on the grounds of WSM quality ranking. For second database Q-WSM has not yet developed quality system.

The quality ranking system of World Stress Map clarifies data providing a possibility to comparison data for the use in analyzing stress patterns and the interpretation of geodynamic processes. Five grades from A to E describe quality of measurements, with A being the highest quality and E the lowest. Grades A, B and C indicate that the orientation of the maximum horizontal compressional stress σ_H is accurate to within ±15°, ±15 - 20° and ±20 - 25°. For the most methods these quality classes are defined through the standard deviation and the measurement depth of σ_H. Grade D indicate questionable direction of ±25 - 40° and grade E no reliable information or the standard deviation of greater than ±40°. WSM suggests that only grades A, B and C are considered reliable for the use in analysing stress patterns and the interpretation of geodynamic processes

The quality classification is mainly based on the number, accuracy and depth of the measurements. The WSM quality ranking classification was introduced by Zoback & Zoback (1989), and Zoback & Zoback (1991), and then refined and extended by Sperner *et al.* (2003) as well as Heidbach *et al.* (2010). It is internationally accepted and guarantees reliability and global comparability of the stress data.

Quality ranking has been done according to WSM classification basis using mean value and standard deviation of the orientations of maximum horizontal stress from each hole.

Table 2. World Stress Map quality ranking system version 2008 for contemporary orientation of maximum horizontal compressional stress.

Stress indicator		A S_H believed to be within ± 15°	B S_H believed to be within ± 15-20°	C S_H believed to be within ± 20-25°	D Questionable S_H orientation (± 25-40°)	E no reliable information (> ± 40°)
Focal Mechanism (FM)	**Formal Inversion (FMF)**	• Formal inversion of ≥ 15 well constrained single event solutions in close geographic proximity and s.d. or misfit angle ≤ 12°	• Formal inversion of ≥ 8 well constrained single event solutions in close geographic proximity and s.d. or misfit angle ≤ 20°	-	-	-
	Single (FMS)	-	-	• Well constrained single event solution, M ≥ 2.5 (e.g. CMT solutions)	• Well constrained single event solution, M < 2.5	• Mechanism with P,B,T axes all plunging 25°-40° • Mechanism with P and T axes both plunging 40°-50°
	Average (FMA)	-	-	-	• Average of P-axis trends or circular statistics of P-axis trends • Composite solutions	
Borehole Breakout (BO)	from caliper logs	• ≥ 10 distinct breakout and combined length ≥ 300 m in a single well with s.d. ≤ 12°	• ≥ 6 distinct breakout and combined length > 100 m in a single well with s.d. ≤ 20°	• ≥ 4 distinct breakouts and combined length ≥ 30 m with s.d. ≤ 25°	• < 4 distinct breakouts or < 30 m combined length in a single well with s.d. ≤40°	• Wells without reliable breakouts or s.d. > 40°
	from image logs	• ≥ 10 distinct breakout zones and combined length ≥ 100 m in a single well with s.d. ≤ 12°	• ≥ 6 distinct breakout zones and combined length > 40 m in a single well with s.d. ≤ 20°	• ≥ 4 distinct breakouts and combined length ≥ 20 m with s.d. ≤ 25°	• < 4 distinct breakouts or < 20 m combined length in a single well with s.d. ≤40°	
Drilling Induced Fractures (DIF)		• ≥ 10 distinct fracture zones in a single well with a combined length ≥ 100 m and s.d. ≤ 12°	• ≥ 6 distinct fracture zones in a single well with a combined length ≥ 40 m and s.d. ≤ 20°	• ≥ 4 distinct fracture zones in a single well with a combined length ≥ 20 m and s.d. ≤ 25°	• < 4 distinct fracture zones in a single well or a combined length < 20 m and s.d. ≤ 40°	• Wells without fracture zones or s.d. > 40°
Hydraulic Fracture (HF)		• ≥ 5 hydrofrac orientations in a single well with s.d. ≤ 12° • depth ≥ 300 m, and distributed over a depth range ≥ 300 m	• ≥ 4 hydrofrac orientations in a single well with s.d. ≤ 20° • depth ≥ 100 m, and distributed over a depth range ≥ 200 m	• ≥ 3 hydrofrac orientations in a single well with s.d. ≤ 25° • depth ≥ 30 m, and distributed over a depth range ≥ 100 m	• Single hydrofrac orientation	• Wells in which only stress magnitudes are measured, without information on orientations
Overcoring (OC) and **Borehole Slotter (BS)**		• ≥ 11 measurements with depth ≥ 300 m and s.d. ≤ 12°	• ≥ 8 measurements with depth ≥ 100 m and s.d. ≤ 20°	• ≥ 5 measurements with depth ≥ 30 m and s.d. ≤ 25°	• ≥ 2 measurements with depth ≥ 10 m and s.d. ≤ 40°	• < 2 measurements or depth < 10 m or s.d. > 40° • Measurements in boreholes extending less than two excavation radii from the excavation wall • Distance to topographic features less than three times the height of the topographic feature
Fault Slip (GF)		• Inversion of ≥ 25 fault-slip data with a fluctuation ≤ 9° for ≥ 60% of the whole dataset	• Inversion of ≥ 15 fault-slip data with a fluctuation ≤ 12° for ≥ 45% of the whole dataset	• Inversion of ≥ 10 fault-slip data with a fluctuation ≤ 15° for ≥ 30% of the whole dataset • Attitude of fault and primary sense of slip known, no actual slip vector	• Inversion of ≥ 6 fault-slip data with a fluctuation ≤ 18° for ≥ 15% of the whole dataset • Offset core holes • Quarry popups • Postglacial surface fault offsets	-
Volcanic Vent Alignment (GVA)		• ≥ 5 Quaternary vent alignments or "parallel" dikes with s.d. ≤ 12°	• ≥ 3 Quaternary vent alignments or "parallel" dikes with s.d. ≤ 20°	• Single well-exposed Quaternary dike • Single alignment with ≥ 5 vents	• Volcanic alignment inferred from < 5 vents	-
Petal Centerline Fractures (PC)		-	-	• Mean orientation of fractures in a single well with s.d. ≤ 20°	-	-

3 Finnish measurements

WSM is meant to collect information about the regional stress. Near-surface stress measurements are given the lowest quality in the criteria used by WSM because they are not believed to be reliably indicative of the regional stress. It is believed that only stress measurements made at depths greater than 100 m are indicative of the tectonic stress field at midcrustal depths. The most measurements in Finland have been done near surface. Local geological structures might change locally the orientation and magnitude of stress components.

In situ stress measurements in Finland has been done in over 150 measurement locations from year 1961 until today. Measurements has been done with typical and worldwide accepted methods. The surface is the most typical starting point for measurements, but reliability and success of measurements under surface has been significant research subject during last ten years in Olkiluoto research area.

Finnish rock stress measurements have been collected earlier in five occasions. First collection of Finnish *in situ* rock stress measurements was done in year 1981 (Vuorimiesyhdistys 1981). Finland participated to accumulate Fennoscandian Rock Stress Data Base (FRSDB) in year 1986 (Stephansson *et al.* 1987). Last published update to Finnish rock stress measurement data was done in KR-2000 project in year 1994 (Tolppanen & Johansson 1996). Last Finnish update in the World Stress Map database was done in year 1999 by Pasi Tolppanen (Tolppanen & Särkkä 1999).

Only measurements about primary stress state has been taken in account. For example Agnico Eagle Oy in Kittilä mine had a measurement about secondary stress state which was not taken to the thesis.

3.1 Problems in older Finnish WSM data

An Automatic country naming locates data in WSM on the grounds of latitude and longitude information. Modern mapping locates measurement places by the seaside to sea, if the exact place from coordinates are not onshore. Because many measurement places locates near at sea coast, some measurement places has been changed to locate at sea and not in Finland. Because of that, some corrections have been made to longitude and latitude information of old Finnish data in WSM and has been sent to Oliver Heidbach the head of GFZ, to get all old Finnish data information back to Finland. Seventeen Finnish data rows has been changed back from “Sea” to Finland according to corrected latitude and longitude coordinates. After changes it is possible to find 77 data rows in Finland instead of only 60. In addition, some corrections have been made to restore some incorrect changes in Finnish WSM data in data transfers between data versions 2008 and 2016.

3.2 Mines and deep holes

First LVDT measurements in Elijärvi mine / Kemi mine has been done in January and February 2014 at a depth of 400 m (See row 140 Appendix 1); (Hakala & Heine 2014) In October 2015 LVDT measurements continued in Elijärvi mine at a depth of 860 m (See row 141 Appendix 1); (Hakala & Heine 2015). The Elijärvi mine data of year 2001 CSIRO overcoring measurement in 553 m for WSM can be found in Row 22 Appendix 1. (Kivinen & Varis 2001).

Pyhäsalmi mine is located in Pyhäsalmi. The mine has seven earlier overcoring WSM data records. Four of the measurements are quality E (200m, 200m, 290m, 390m), one is quality D (420m), one is quality B (1999) and one quality A (290m). Malmi Oy has done overcoring measurements in Pyhäsalmi mine in year 2000. The data is in Row 21 Appendix 1. LVDT measurement in Pyhäsalmi mine has been done in 2014. The data is in Row 144 Appendix 1.

Kylylahti mine is located in Polvijärvi in Eastern Finland. LVDT measurements in Kylylahti has been made in 2013 and in 2015. Summaries of reports have been given to the thesis. From year 2013 the Kylylahti mine data is in Row 138 Appendix 1. From year 2015 the Kylylahti mine data is in Row 147 Appendix 1.

In geothermal deep hole of St1 in Otaniemi has been done hydraulic fracturing measurements for breakdown or maximum pressures and shut-in pressures in October 2015. 9 measurements succeeded from 13 Hydrofrac-tests. Stress directions have not been investigated. (Becker 2015)

The 2.5 km deep hole in Outokumpu has been drilled for research purposes in 2004 – 2005 by Geological Survey of Finland (Kukkonen 2011). However, in that OKU-hole has not been done any hydraulic fracturing or other rock stress estimations. Nor there has not been done biaxial tests from core samples to get rock mechanics determinations. In 2017 Kukkonen (2017) has done stress orientation analyzing on the grounds of borehole wall outbreaks. Outbreaks starts to appear at the depth of about 1600 m. The maximum depth of the used ultrasonic borehole televiewer has been at the depth of 1900 m. The televiewer instrument yield detailed information about wellbore failure that is important in assessing stress orientation at depth (Zoback *et al.* 2003). The orientation of major horizontal rock stress in a hole is in a slightly different direction than usually in Finland. The results of the research will be published in near future. (Kukkonen 2017)

3.3 Espoo

Suomen Malmi Oy has done overcoring measurements in Leppävaara (rock shelter) with Borre cells in July 1998 at a depth of 11 to 21 m in one 76 mm hole. Measuring and reporting was done by Vattenfall Hydropower AB. The objective of measurement, 5 successful measurements, almost was fulfilled, when 4 measurements succeeded from 8 attempts in 19 pilot holes. The biaxial testing was not possible for different reasons. The information for elastic parameters, Young's modulus and Poisson's ratio, was taken from old stress measurements in Espoo and from other rock mechanical testing on the same rock type. (See Rows 1-4 Appendix 3). (Ljunggren & Andersson 1998)

Suomen Malmi Oy has done hydraulic fracturing measurements in three 38 mm holes, JTM-1, JTM-2 and JTM-4, in Tapiola Hakalehto in August and September 2000 at a depth of 4 to 23 m. 12 measurements succeeded from 30 making possible to calculate horizontal direction and magnitude. Near measurement place is a weakness fracture in a direction of about 20 degrees inducing major or minor horizontal orientation to follow it and inducing variety in results. Because of large standard deviation, results from all three holes were merged and the quality ranking became E, the worst (see Row 31 Appendix 1). (Mononen 2000e)

Suomen Malmi Oy has done hydraulic fracturing measurements in two 38 mm holes, SK-3006 and SK-3007, in Mestarintunneli road tunnel in December 2005 at a depth of 5 to

14 m. Only 1 measurement succeeded from 9 making possible to calculate horizontal direction (see Row 67 Appendix 1). (Majapuro 2005c)

Suomen Malmi Oy has done hydraulic fracturing measurements in Mestarintunneli road tunnel in September 2006 in one 38 mm hole, 3012, at a depth of 12 to 25 m. 2 measurements succeeded from 8 making possible to calculate horizontal direction. However only one measurement has been used for the orientation, because tensile strength for the second succeeded measurement was small. Frequent fractures made measurements problematic to succeed. Results were calculated using dt/dP vs P (See Row 70 Appendix 1). (Varis & Sipola 2006)

Suomen Malmi Oy has done hydraulic fracturing measurements in two 46 mm holes, JT-1020 and JT-1021, in Tapiola parking hall in April 2010 at a depth of 11 to 29 m. 14 measurements succeeded from 20 making possible to calculate horizontal orientation, but because a standard deviation was over 40 degrees, there was no reliable orientation. 10 measurements created horizontal fracture preventing measurement of horizontal magnitude. The measurement report estimated, that an orientation of JT-1020 could be 95 degrees and an orientation of JT-1021 could be 90 degrees, but because of large standard deviation rankings were set to E meaning no orientation (see Rows 114-115 Appendix 1). (Kivinen & Varis 2010a)

Suomen Malmi Oy has done hydraulic fracturing measurements in three 46 mm holes, JT101, JT102 and JT103, in Espoo Blominmäki in April and in May 2010 at a depth of 10 to 29 m. 24 measurements succeeded from 29 making possible to calculate horizontal direction and in 23 measurements it was possible to calculate horizontal magnitude. Major and minor horizontal magnitudes of holes were combined but major horizontal orientations separated (see Rows 103-105 Appendix 1). (Kivinen & Varis 2010b)

Suomen Malmi Oy has done hydraulic fracturing measurements for the metro extension in Espoo 2007 - 2009 and 2013 - 2014.

In 2007 from September to December hydraulic fracturing Minifrac System equipment has been used in twelve 46 mm holes, two holes in each six locations, at a depth of 8 to 27 m. 69 measurements succeeded from 109 making possible to calculate horizontal orientations and in 87 measurements it was possible to calculate horizontal magnitudes. (Varis 2008a)

Specifications of those measurements consists of as follows:

- Matinkylä: 0/11 orientations and 9/11 magnitudes succeeded in holes JT501 and JT502 (see Row 62 Appendix 1 and Rows 423-433 Appendix 2)
- Olarinluoma: 15/20 orientations and 13/20 magnitudes succeeded in holes JT2501 and JT2502 (see Rows 63-64 Appendix 1 and Rows 434-448 Appendix 2)
- Niittymaa: 15/20 orientations and 19/20 magnitudes succeeded in holes JT3501 and JT3502 (see Rows 65-66 Appendix 1 and Rows 449-467 Appendix 2)
- Tapiola: 9/18 orientations and 11/18 magnitudes succeeded in holes JT4501 and JT4502 (see Rows 67-68 Appendix 1 and Rows 468-478 Appendix 2)
- Otaniemi: 16/20 orientations and 20/20 magnitudes succeeded in holes JT6501 and JT6502 (see Rows 69-70 Appendix 1 and Rows 479-498 Appendix 2)
- Keilaniemi: 15/20 orientations and 15/20 magnitudes succeeded in holes JT7501 and JT7502 (see Rows 71-72 Appendix 1 and Rows 499-513 Appendix 2).

In 2008 from April to June measurements continued in Matinkylä and Tapiola. Hydraulic fracturing Minifrac System equipment has been used in four 46 mm holes, again two holes in both locations at a depth of 12 to 29 m. 21 measurements succeeded from 51 making possible to calculate horizontal orientations. In 23 measurements it was possible to calculate horizontal magnitudes. First results were calculated using tensile strength from the sum of the breakdown pressure (P_b) and the reopening pressure(P_r). There were also alternative results calculated using tensile strength defined in laboratory. The alternative results were about two times as big as first results. The real results were estimated to be somewhere between two results. (Kivinen & Varis 2008)

Specifications of those measurements consists of as follows:

- Matinkylä: 3/14 orientations and magnitudes succeeded in hole JT09 (see Row 84 Appendix 1)
- Matinkylä: 1/10 orientations and magnitudes succeeded in hole JT12 (see Row 84 Appendix 1)
- Tapiola: 8/9 orientations and 9/9 magnitudes succeeded in hole JT34 (see Row 85 Appendix 1)
- Tapiola: 9/11 orientations and 10/11 magnitudes succeeded in hole JT36 (see Row 86 Appendix 1).

In 2013 from March to July measurements around the metro extension continued. Hydraulic fracturing Minifrac System equipment has been used in 24 46 mm holes, about three in each location, always at a depth of under about 30 m.

In Espoonlahti and Kivenlahti has been done measurements in 3 holes, JT-10, JT-11 and JT-17. 4 measurements succeeded from 30 making possible to calculate horizontal orientations, and in 9 measurements it was possible to calculate horizontal magnitudes. The data in WSM was updated (see Rows Appendix 1) and new data for Q-WSM was prepared (see Rows 139-140 Appendix 1). (Tarvainen 2013a)

In Kivenlahti has been done measurements in 3 holes, JT-12, JT-13 and JT-14. The data in WSM was updated and new data for Q-WSM was prepared (see Rows 130-132 Appendix 1). (Tarvainen 2013b)

In Saunalahti has been done measurements in April 2013 in a hole, JT-15, at a depth of 15 to 32 m. The data in WSM was updated and new data for Q-WSM was prepared (see Row 134 Appendix 1). (Tarvainen 2013c)

In Suomenoja has been done measurements in 5 holes, JT-1, JT-2, JT-3, JT-18 and JT-19. The data in WSM was updated and new data for Q-WSM was prepared (see Rows 135-137 Appendix 1). (Tarvainen 2013d)

In Kaitaa has been done measurements in 4 holes, JT-4, JT-5, JT-6 and JT-20. The data in WSM will be updated and new data for Q-WSM will be prepared. (Tarvainen 2013e)

In Soukka has been done measurements in 4 holes, JT-7, JT-8, JT-9 and JT-21. The data in WSM will be updated and new data for Q-WSM will be prepared. (Tarvainen 2013f)

In Soukka has been done measurements in 4 holes, JT-22, JT-23, JT-24 and JT-25. The data in WSM will be updated and new data for Q-WSM will be prepared. (Tarvainen 2013g)

Suomen Malmi Oy with subcontractor Statens Vattenfallsverk has done overcoring measurements with Hiltscher-Leeman method in Espoo Kiltakallio shelter near Espoo City in September and October 1986 at a depth of 12 to 40 m. From 7 measurements 6 succeeded making possible to calculate horizontal orientations and magnitudes. Near measurement holes is a weakness joint in a direction of about 20 degrees. Because horizontal major and minor stresses are near each other, both horizontal stresses alternate in a direction of joint. The old data was prepared for Q-WSM, but is not seen in this thesis. (Varis 2001)

3.4 Helsinki

Helsinki is the capital of Finland and therefore most Finnish rock stress measurements have been done in Helsinki. The oldest measurement in WSM in Helsinki is made in 1985 in Viikinmäki sewage treatment plant. The latest measurement in WSM in Helsinki is made in 1997 in Kluuvi. In 1997 in Haaga four Leeman overcoring measurements were done at a depth of 9 to 20 m. This data is not in Appendix. (Tolppanen & Johansson 1996)

In 1985 Viikinmäki sewage treatment plant 12 Hast overcoring measurements in three holes were done at a depth of 11 to 22 m, on average 17 m. The result of stress direction was 141 degrees. A standard deviation of measurements is unknown. In 1987 in Viikinmäki sewage treatment plant 6 Leeman-Hiltscher overcoring measurements in one hole was done at a depth of 16 to 33 m, on average 24 m. The result of stress direction was 24 degrees with standard deviation of 24 degrees. In 1990 in Viikinmäki sewage treatment plant 20 Leeman-Hiltscher overcoring measurements in three holes was done at a depth of 15 to 50 m, on average 29 m. The result of stress direction was 18, 142 and 154 degrees with standard deviation of 36 - 38 degrees. The data is not in Appendix. (Tolppanen & Johansson 1996)

In 1988 in Kamppi Bus Station 4 Leeman overcoring measurement was done in the depth of 4 to 10 m. The result of stress direction was 138 with standard deviation of 16 degrees with the quality of E. In 1989 in Kamppi Bus Station 6 Leeman overcoring measurement was done in the depth of 5 to 17 m. The result of stress direction was 43 with standard deviation of 38 degrees with the quality of D. In 1989 in Kamppi Bus Station one Leeman overcoring measurement was done in the depth of 10 m. The result of stress direction was 122 with the quality of E. The data is not in Appendix. (Tolppanen & Johansson 1996)

Suomen Malmi Oy has done overcoring measurements in Mellunmäki with Leeman cell in three holes in September 1998 at a depth of 10 to 29 m. Biaxial testing was done to biaxial cell with 4 – 20 MPa compression. The new data for WSM and Q-WSM was prepared (see Rows 5-7 Appendix 1). (Ihalainen 1998)

Suomen Malmi Oy has done hydraulic fracturing measurements in Kamppi Center in November 2000 in two 38 mm holes, MP1 and MP2, at a depth of 7 to 18 m. 2 measurements succeeded from 8 making possible to calculate horizontal direction. However, tensile strength of other measurement was minor, so only one measurement has been used for the result. Frequent fractures made measurements problematic. Results were calculated using dt/dP vs P (See Row 19 Appendix 1). (Mononen 2000a)

Suomen Malmi Oy has done overcoring measurements in Salmisaari with CSIRO HI cell (Mindata Australia Pty Ltd) in hole JTM4 in three consecutive measurements in the beginning of September 2000 in depth under 30 m (10-29 m). Measurement started with a 70 cm long pilot hole in 38 / 22 mm diametre. Biaxial testing was done after overcoring in biaxial cell with a 4 – 20 MPa compression. The new data for WSM and Q-WSM was prepared (see Row 18 Appendix 1). (Mononen 2000b)

Suomen Malmi Oy has done overcoring measurements in Salmisaari underground coal storage with Borre cell in February 2000 at a depth of 53 to 116 m in three 76 mm holes, JMT1, JMT2 and JMT3, to design an underground facility. Technical work was done during five weeks by Swedpower AB together with Suomen Malmi Oy. Aim was to measure in six separate depth level from 50 to 120 m. The result was 17 successful measurements: 5 times in JMT1, 6 times in JMT2 and 6 times in JMT3. Measurements were done in every hole at the same six depths. All three holes were within 200 m radius of each other. Because of that six data records were added to WSM. The depth levels are 55 m, 68 m, 78 m, 86 m, 100 m (only 2 measurements) and 115 m. According to measurements at the depth of 50 to 120 m, horizontal stress values (σ_H, σ_h) are greater than expected and vertical stress (σ_v) is unusually high comparing to rock mass above. The major horizontal stress grows from 50 to 120 m (from 9 MPa to 14 MPa) (Table 3). The minor horizontal stress grows from 50 to 80 m (from 6 MPa to 8 MPa), decreases fast back and grows again from 85 to 120 m (from 5 MPa to 10 MPa) (Table 3). The dispersion of major horizontal stress orientation is large but on the whole between west and north-west. The rock is mainly medium granular granite which has some gneiss stripes. Gneiss trend is 30 degrees from hole dip. Values of Young's modulus (E) measured from rock samples are in normal range: granite 70 GPa and gneiss 88 GPa. Values of Poisson's ratio (ν) are mainly between 0,21 to 0,32. Because the range is so large, dispersion is large. Part of the data to WSM can be seen in Table 3. (See Rows 12-17 Appendix 1) (Klasson 2000)

Table 3. Data records to WSM from Salmisaari Helsinki.

TYPE	DEPTH	QUA	LOCALITY	NR	AZI	S1	S2	S3
OC	0,055	C	SALMISAARI JTM1/2/3	3	88	9	6	3
OC	0,068	C	SALMISAARI JTM1/2/3	3	159	10	8	1
OC	0,078	C	SALMISAARI JTM1/2/3	3	95	10	8	5
OC	0,086	C	SALMISAARI JTM1/2/3	3	46	12	5	6
OC	0,100	C	SALMISAARI JTM1/2/3	2	119	13	6	4
OC	0,115	C	SALMISAARI JTM1/2/3	3	142	14	10	7
OC	0,014	D	SALMISAARI JTM4	3	120	15	7	3
HF	0,012	D	SALMISAARI JTM-5/6/7/8	7	145	10,5	8	0,3

Suomen Malmi Oy has done hydraulic fracturing measurements in four 38 mm holes, JMT5, JMT6, JMT7, JMT8, in Salmisaari in September 2000 at a depth of 7 to 17 m. 7 measurements succeeded from 27 making possible to calculate horizontal orientation. The results from four holes, JMT5, JMT6, JMT7, JMT8, were merged and the quality ranking is the worst, E (see Row 19 Appendix 1). (Mononen 2000c)

Suomen Malmi Oy has done hydraulic fracturing measurements under the street Arkadiankatu, near Finnish museum of natural history, in January 2001 in three 38 mm holes, JTM1, JTM2 and JTM3, at a depth of 9 to 23 m. 10 measurements succeeded from 25 making possible to calculate horizontal orientations and in 17 measurements it was possible to calculate horizontal magnitudes. Rock in the JTM3 was better suitable for hydraulic fracturing than in JTM1 or in JTM2. 8 of succeeded measurements were at a depth of 16 to 22 m. The new data for WSM and Q-WSM was prepared (see Rows 26-28 Appendix 1). (Mononen 2001b)

Suomen Malmi Oy has done hydraulic fracturing measurements with Minifrac System in two 38 mm holes, JMT4 and JTM5, in Kamppi Center in January and February 2002 at a depth of 7 to 26 m. JMT4 was located in underground basement and JMT5 at surface. 4 measurements succeeded from 20 making possible to calculate both horizontal direction and magnitudes. In the first hole, JMT4, two measurements, at a depth of 11 m and at a depth of 21 m, were about the same horizontal orientation to get a decent result. In the second hole, JMT5, was not possible to get an acceptable result for horizontal orientation. Also, in JMT5, second acceptable measurement, minor magnitude (σh),was larger than major magnitude (σH), so the stress came from one measurement. The new data for WSM and Q-WSM was prepared (see Rows 31-32 Appendix 1). (Mononen 2002).

Suomen Malmi Oy has done overcoring measurements in Kamppi Center in February and April 2002 with CSIRO HI cell in two holes, JMT1 at a depth of 15 m, and JMT2 at a depth of 17 to 22 m. The measurement started with a 38 / 22 mm diameter, 70 cm pilot hole. Biaxial testing was done after overcoring. The new data for WSM and Q-WSM was prepared (see Rows 29-30 Appendix 1). (Hakala & Tolppanen 2002).

Suomen Malmi Oy made hydraulic fracturing measurements in January 2003 in Vuosaari harbor (Porvarinlahti) at a depth of 10 to 22 m. 6 measurements were done using one 38 mm hole HF-1. The new data for WSM and Q-WSM was prepared (see Row 44 Appendix 1). (Mononen 2003e)

Suomen Malmi Oy made hydraulic fracturing measurements in Vuosaari tunnel during the Vuoli-project in February, March and April 2004 at a depth of 10 to 22 m. 45 measurements were done using three 38 mm holes, JMT1, JMT2 and JMT3. The new data for WSM and Q-WSM was prepared (see Rows 51-52 Appendix 1). (Majapuro 2004b)

Suomen Malmi Oy made hydraulic fracturing measurements in Kumpula underground electric station in December 2004 at a depth of 8 to 27 m. 14 measurements were done using Minifrac System in three 38 mm holes JTM1, JTM2 and JTM3. 11 measurements were considered successful. Rock in JTM1 and JTM2 is amphibolite with grain size from 0,5 mm to 4 mm and in JMT3 rock is rough-grained pegmatite with grain size from 5 mm to 30 mm. The major horizontal stress directions are 80 degrees (3 measurements in JMT1), 120 degrees (4 measurements in JMT2) and 58 degrees (4 measurements in JMT3). Between JMT1/JMT2 and JMT3 is a fracture zone. Based on successful results the major horizontal stresses are 14,1 MPa (JMT1), 14,3 MPa (JMT2) and 7,7 MPa (JMT3). The minor horizontal stresses are 7,1 MPa (JMT1), 7,3 MPa (JMT2) and 4,1 MPa (JMT3) The new data for WSM and Q-WSM was prepared (see Rows 46-48 Appendix 1). (Majapuro 2004d)

Suomen Malmi Oy made hydraulic fracturing measurements in Kluuvi underground electric station under Kolmensepänaukio, located in the crossing of Aleksanterinkatu and

Mannerheimintie, in December 2003 at a depth of 13 to 28 m. 10 measurements were done using Minifrac System in one 38 mm hole JTM. 4 measurements were considered good enough for a stress state evalution. Unsuccessful measurements came from broken rock. Rock is medium grain size granite. The new data for WSM and Q-WSM was prepared (see Row 37 Appendix 1). (Majapuro 2003c)

Suomen Malmi Oy has done hydraulic fracturing measurements in Helsinki City Center in February 2004 with Minifrac System in one 38 mm hole, JTM, at a depth of 4 to 17 m. 4 measurements succeeded from 10 making possible to calculate both horizontal direction and magnitudes. Almost all unsuccessful measurements failed because of horizontal fractures. Results have been digitized for calculation of stress field. The shut-in pressure (Ps) has been defined using two separate calculation methods. With the help of Log(P) – method is solved lowest shut-in pressure. It is selected from the point, where pressure remain constant. With the help of dT/dP vs P –method is solved highest shut-in pressure. The new data for WSM and Q-WSM was prepared (see Row 45 Appendix 1). (Majapuro 2004a).

Suomen Malmi Oy has done hydraulic fracturing measurements in Stockmann parking garage under the street of Mannerheimintie in March and April 2003 with Minifrac System in two 38 mm holes, JTM1, JMT2 and JTM3, at a depth of 7 to 27 m. 21 measurements succeeded making possible to calculate horizontal orientations, and 28 succeeded making possible to calculate reliable horizontal magnitudes. The new data for WSM and Q-WSM was prepared (see Row 40 Appendix 1). (Mononen 2003c).

Suomen Malmi Oy has done hydraulic fracturing measurements in Stockmann parking garage under the street of Mannerheimintie in March and April 2003 with Minifrac System in two 38 mm holes, JTM201 and JTM202, at a depth of 12 to 26 m. 9 measurements succeeded from 10 making possible to calculate horizontal magnitudes, but only 4 succeeded making possible to calculate reliable horizontal orientations. Almost all unsuccessful measurements were because of horizontal fractures. Results have been digitized for calculation of stress field. The shut-in pressure (Ps) has been defined using two separate calculation methods. Lowest shut-in pressure is solved with the help of Log(P) method. It is selected from a point, where pressure remains constant. Highest shut-in pressure is solved with the help of dT/dP vs P method. The new data for WSM and Q-WSM was prepared (see Rows 41-42 Appendix 1). (Mononen 2003d).

Suomen Malmi Oy has done hydraulic fracturing measurements with Minifrac System in one 38 mm hole, JTM1, in Vallila parking garage in July 2004 at a depth of 14 to 20 m. Rock in JTM1 is mid-to-rough-grained granite with grain size from 2 mm to 5 mm. Stray grain size is from 10 mm to 20 mm. 6 measurements succeeded from 10 making possible to calculate magnitudes and horizontal directions. Results have been digitized. The shut-in pressure (Ps) has been defined using two separate calculation methods. With the help of Log(P) method is solved lowest shut-in pressure. It is selected from the point, where pressure remain constant. With the help of dT/dP vs P method is solved highest shut-in pressure. The new data for WSM and Q-WSM was prepared (see Row 49 Appendix 1). (Majapuro 2004c).

Suomen Malmi Oy has done overcoring measurements in Kamppi Center with CSIRO HI cell in February 2005 at a depth of 22 m to 25 m. All three measurements, two in hole JMT1 and one in hole JMT2, were successful and were used for calculationa of principal stresses. Measurement started with 70 cm long pilot hole in 38 / 22 mm diametre. Biaxial loading and testing was done after overcoring in biaxial cell with a MPa compression. The new data for WSM and Q-WSM was prepared (see Rows 53-54 Appendix 1). (Majapuro 2005b).

Suomen Malmi Oy has done hydraulic fracturing measurements in one 38 mm hole, JMT1, in Kauppakartano collective shelter in September 2006 at a depth of 4 to 11 m. From 10 measurements all succeeded making possible to calculate magnitudes, but only 6 succeeded to calculate horizontal orientations. The average major horizontal orientation of 6 measurements is 110 degrees with standard deviation of 57%. After ignoring the measurement at a depth of 4 m, average major orientation is 129 degrees with a standard deviation of 36% That is enough for quality ranking D. It is not possible to get higher ranking because of near surface measurements. The new data for WSM and Q-WSM was prepared (see Row 58 Appendix 1). (Varis 2006)

Suomen Malmi Oy has done hydraulic fracturing measurements in three 46 mm holes in Helsinki for the metro extension in 2007 from November to December at a depth of 8 to 27 m. 20 measurements succeeded from 28 making possible to calculate horizontal direction and in 19 measurements it was possible to calculate horizontal magnitude. (Kivinen & Varis 2008b)

Suomen Malmi Oy made hydraulic fracturing measurements in November 2007 in Vaskilahti with Minifrac System equipment in 46 mm diameter holes. In only hole 8 measurements succeeded from 10 making possible to calculate horizontal direction and in 10 measurements it was possible to calculate horizontal magnitude. The data to WSM is in row 73 Appendix 1. (Kivinen & Varis 2007)

Suomen Malmi Oy made hydraulic fracturing measurements in December 2007 in Lauttasaari with Minifrac System equipment in 46 mm diameter holes. In the first hole, JT11501, 6 measurements succeeded from 8 making possible to calculate horizontal direction and in 5 measurements it was possible to calculate horizontal magnitudes. In second hole, JT11502, 6 measurements succeeded from 10 making possible to calculate horizontal direction and in 4 measurements it was possible to calculate horizontal magnitudes. From both holes 12 measurements succeeded from 18 making possible to calculate horizontal direction and in 9 measurements it was possible to calculate horizontal magnitudes. The data to WSM is in row 74 Appendix 1. (Kivinen & Varis 2007)

Belonging to metro extension measurements, Suomen Malmi Oy made hydraulic fracturing measurements in November 2009 in Lauttasaari with Minifrac System equipment in 46 mm diameter hole called JT381 at a depth of 14 to 29 m. 5 measurements succeeded from 10 making possible to calculate horizontal magnitude and direction (See row 98 Appendix 1). (Kivinen & Varis 2009b)

Suomen Malmi Oy has done hydraulic fracturing measurements in P-Flemari parking garage in February 2007 in two 38 mm hole, JMT1 and JMT2, at a depth of 4 to 24 m. 8 measurements succeeded from 20 making possible to calculate horizontal orientation and 16 measurements succeeded from 20 making possible to calculate horizontal magnitude. The new data for WSM and Q-WSM was prepared (see Rows 75-76 Appendix 1). (Varis 2007a)

Suomen Malmi Oy has done overcoring measurements using CSIRO HI cell in Helsinki City Spa in August and September 2008 in two holes, JMT1 and JMT2. Three successful measurements at a depth of 10 to 18 m was done. The holes were drilled upwards in the direction of 55 degrees with dip of 5 degrees. The biaxial testing was done with 0 MPa to 10 MPa pressure series using 2,5 MPa step. The new data for WSM and Q-WSM was prepared (see Row 77 Appendix 1). (Tarvainen 2008).

Suomen Malmi Oy has done hydraulic fracturing measurements with Minifrac System in three 46 mm hole, JTM1, JMT2 and JMT3, in Helsinki City Spa in July 2008 at a depth of 10 to 28 m. Measurements in JMT2 did not succeeded. Rock in JTM1 is quartzdiorite and rock in JTM3 is granite. 10 measurements succeeded from 29 making possible to calculate magnitudes and horizontal directions. Results have been also digitized. The shut-in pressure (Ps) has been defined using two separate calculation methods. With the help of Log(P) method is solved lowest shut-in pressure. It is selected from the point, where pressure remain constant. With the help of dT/dP vs P method is solved highest shut-in pressure. The new data for WSM and Q-WSM was prepared (see Rows 78-79 Appendix 1). (Varis & Kivinen 2008).

Suomen Malmi Oy has done three overcoring measurements in Meilahti hospital garage in February 1997 at depth under 30 m. Core samples were studied in Technology University of Helsinki. All three measurements. The data from JMT5 to WSM is LAT 60,190, LON 24,900, AZI 75, depth 0,019 km, quality D, number 8, SD 38, MAG_INT_S1 17,0 MPa, MAG_INT_S2 6,1 MPa, rock unknown. The new data for WSM and Q-WSM was prepared (see Row 2 Appendix 1). (Varis & Tarvainen, 2008)

Suomen Malmi Oy has done 5 succeeded overcoring measurements in Meilahti hospital area in February 2005 in two holes, JTM1 and JTM2, in a depth of 11 to 27 m. Core samples were studied in Technology University of Helsinki. The new data for WSM and Q-WSM was prepared (see Row 55 Appendix 1). (Majapuro 2005d)

Suomen Malmi Oy has done hydraulic fracturing measurements in Meilahti parking garage and Meilahti hospital in January 2008 in two 46 mm holes, JTM3 and JTM4, in a depth of 9 to 26 m. 8 measurements succeeded from 10 in JMT3 and 7 measurements succeeded from 10 in JTM4 making possible to calculate horizontal direction. Horizontal stresses in JTM3 are considerable large, but in JTM4 horizontal stresses are about normal comparing to usual situation in the bedrock of Finland. The new data for WSM and Q-WSM was prepared (see Rows 81-82 Appendix 1). (Varis 2008c)

Suomen Malmi Oy has done overcoring measurements in two holes, JMT5 and JMT6, in Meilahti parking garage and Meilahti hospital in February and March 2008 at a depth of under 30 m. Only one measurement succeeded making possible to calculate horizontal orientation. The new data for WSM and Q-WSM was prepared (see Rows 83 Appendix 1). (Varis & Tarvainen, 2008)

Suomen Malmi Oy has done CSIRO HID overcoring measurements in April 2014 in Kalasatama. Ten measurements were done in one 38 mm hole. The new data for WSM and Q-WSM was prepared (see Row 139 Appendix 1). (Varis & Kivinen 2014)

Two LVDT measurements has been made in Helsinki City Rail Loop (Pisararata) in November 2015. Three successful measurements have been done in the northern half of station. In the southern half of station has been done four successful, one unsuccessful and one abandoned measurement. Photographing has been done with 3D photogrammetry. Elastic rock characteristics has been determined with axial testing. According to two measurements, southern measurement place, MP2, was succeeded better than northern measurement place, MP1, and therefore used prior to other. The new data for WSM and Q-WSM was prepared (see Row 146 Appendix 1). (Hakala *et al*. 2016)

3.5 Lapua, Leppävirta, Mikkeli, Naantali

Suomen Malmi Oy made hydraulic fracturing measurements in Lapua Simpsiö in January 2005 at a depth of 6 to 20 m. 20 measurements were done using Minifrac System in two 38 mm holes, JMT1 and JMT2. 6 measurements were considered successful. The new data for WSM and Q-WSM was prepared (see Row 57 Appendix 1). (Majapuro 2005a)

Helsinki University of Technology has done hydraulic fracturing measurements with Minifrac System in two 38 mm holes, SK9 and SK10, in Leppävirta in January 2003 AT A depth of 7 to 13 m. 6 measurements succeeded technically, but only 3 of them were succeeded to calculate reliable horizontal directions and magnitudes. From those three measurements, one was not acceptable result because σ_h had larger magnitude than σH. Data was calculated using two measurements. Calculations was made using second break-down method. The new data for WSM and Q-WSM was prepared (see Row 38 Appendix 1). (Mononen 2003b).

Helsinki University of Technology has done hydraulic fracturing measurements with Minifrac System in 38 mm hole, SK11, in Leppävirta in February in 2003 at a depth of 11 to 28 m. 10 measurements succeeded must better than measurements in hole SK9 and SK10 The horizontal stress was greater thatn before and the orientation is about 90 degrees from earlier orientation. The orientation is in connection to main fracture orientation from lakes and rivers The new data for WSM and Q-WSM was prepared (see Row 39 Appendix 1). (Mononen 2003b).

Suomen Malmi Oy made hydraulic fracturing measurements in Mikkeli Metsä-Sairila sewage treatment plant in October and November 2009 at a depth of 17 to 28 m using Minifrac System in one 46 mm hole JT1. 7 measurements succeeded from 11. The minor horizontal stress orientation is in average 160 degrees (see Row 148 Appendix 1). (Kivinen & Varis 2009c)

Suomen Malmi Oy made hydraulic fracturing measurements in Mikkeli Metsä-Sairila sewage treatment plant in September 2010 at a depth of 15 to 27 m using Minifrac System in one 46 mm hole JT1. 8 measurements succeeded from 9 (see Row 149 Appendix 1). (Kivinen & Varis 2009c)

Suomen Malmi Oy made hydraulic fracturing measurements in Naantali Tupavuori in February 2008 at a depth of 15 to 29 m using Minifrac System in one 46 mm hole JMT1. 7 measurements succeeded from 11. The horizontal stress orientation is heterogeneous (see Row 87 Appendix 1). (Varis 2008b)

3.6 Olkiluoto

The main rock types of the Olkiluoto area in Eurajoki are in terms of petrographic features and rock composition: 1) migmatitic and veined mica gneisses, 2) quartzitic gneisses, 3) amphibolitic mafic schists, 4) gneissose tonalites or granodiorites and 5) medium-grained granites and leucocratic pegmatites (Gehör *et al.* 1997). The latest geological review of the Olkiluoto area can be found in Aaltonen *et al.* (2016).

At Olkiluoto the maximum horisontal stress increases with depth by approximately 5.6 MPa/1 00 m. (Malmlund & Johansson 2002)

Suomen Malmi Oy has made hydraulic fracturing measurements in four holes in January 2006 in Olkiluoto. From 40 HF measurement 13 succeeded. The new data for WSM and Q-WSM was prepared (see Row 60 Appendix 1). (Majapuro 2006a).

Suomen Malmi Oy has done overcoring measurements using CSIRO HI cell three times in one hole in OL-3 project in March and April 2006 at a depth of 15 to 19 m. All three measurements succeeded. First was done between 24.3.2006 and 27.3.2006 in depth of 15.67 m. Second was done 28.3.2006 in depth of 17.46 m. Third was done 3.4.2006 in depth of 18.56 m. The new data for WSM and Q-WSM was prepared (see Row 61 Appendix 1). (Majapuro *et al.* 2006b)

Suomen Malmi Oy has done hydraulic fracturing measurements with Minifrac System in twenty 56 mm hole in OL-4 project in October, November and December 2010 and in January 2011 at a depth of 10 to 35 m. From 225 measurements 150 succeeded technically, making possible to calculate magnitudes (Figure 28) and horizontal directions (Figure 27). In 80 measurements horizontal fractures prevented defining horizontal stresses (Figure 29). The major horizontal stress from all successful measurements is 4,18 MPa and minor horizontantal stress 2,75 MPa. The direction of major horizontal stress varied in a range of 100 – 280 degrees. (Figure 27). From successful 57 stress measurements, average direction is 99 degrees with s.d. 39%. From second direction results from successful 54 stress measurements average direction is 93 degrees with s.d. 32% (one measurement of 65 degrees is left out because of big difference from other results). From those two direction results average direction is 96 degrees. The new data for WSM and Q-WSM was prepared (see Row 106 Appendix 1). (Tiensuu *et al.* 2011)

The quality of measurements according to quality ranking of Suomen Malmi Oy is following: a large portion of failed orientation measurements, 80, belong to failed quality ranking (4). Those 80 failed measurements indicate horizontal fractures. (Tiensuu *et al.* 2011)

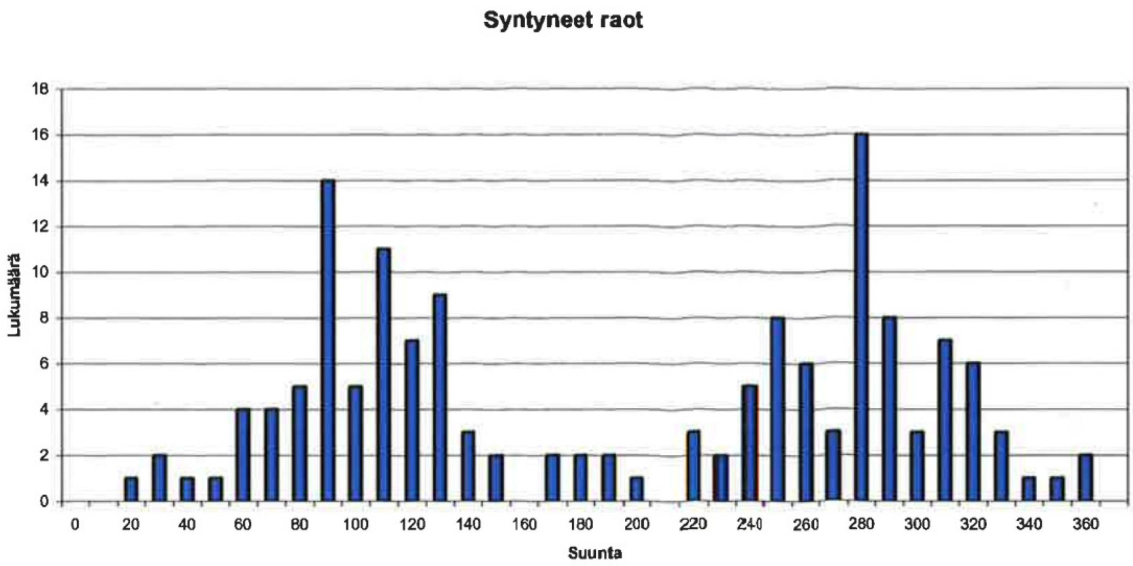

Figure 27. The major horizontal stress direction on the grounds of OL-4 measurements 2010—2011. (Tiensuu et al. 2011)

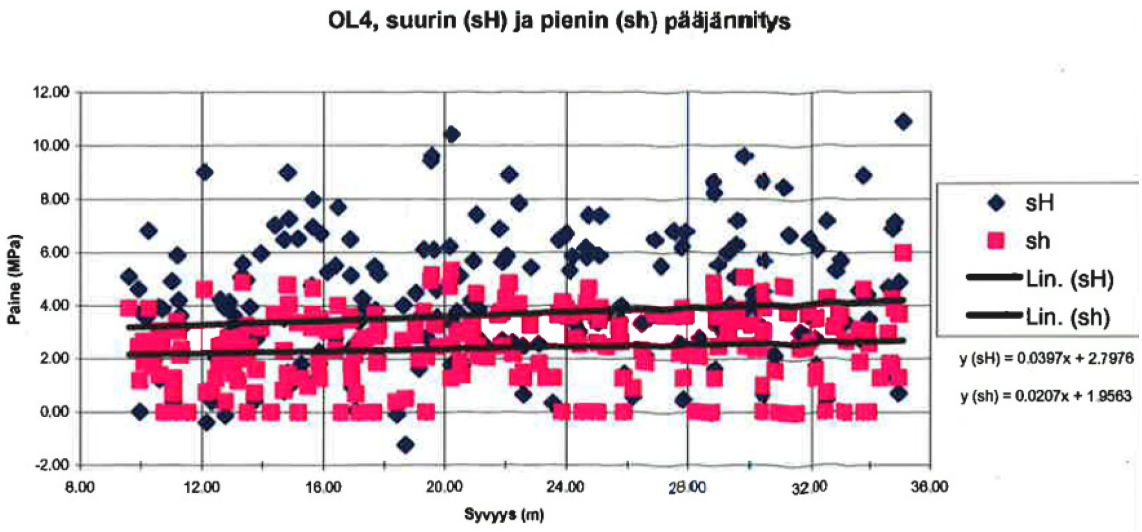

Figure 28. The major and minor horizontal stress magnitudes on the grounds of OL-4 measurements 2010—2011. (Tiensuu et al. 2011)

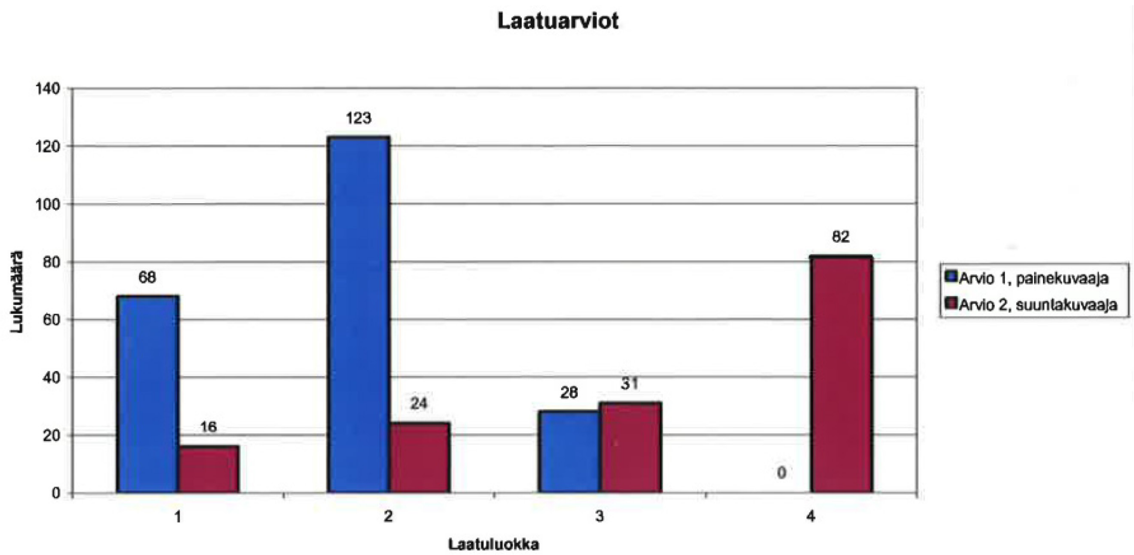

Figure 29. The quality of stresses. Red is for horizontal directions and blue for horizontal magnitudes on the grounds of OL-4 measurements 2010—2011. (Tiensuu et al. 2011)

ONKALO belongs to Olkiluoto area and is a specific research tunnel for measurements. The stress state compared to rock strength in a Olkiluoto area have an influence to placement of nuclear waste structures in a rock mechanics planning.Until year 2006 all rock stress measurements were done only from surface. When ONKALO reached the depth of 120 m, measurements were done also there. In a year 2006 report (Andersson *et al.* 2007) included only measurements on the ground. In a year 2009 report (Posiva 2009) included already measurements in ONKALO tunnel.

In the ONKALO area locates a fragile deformation area at the depth of about 300 m (HZ20A ja HZ20B). Experiments locates either upper or lower from this area. In an area of fragile deformation the stress state changes significantly. (Posiva 2009)

ONKALO measurements (Table 1) are the most in-depth measurements in Finland. Twenty *in situ* rock stress measurements using the LVDT-cell method (Hakala *et al.* 2013) were performed in Posiva Oy's ONKALO investigation facilities during 2009 – 2014 (Hakala *et al.* 2016). The measurements cover a depth range of 156 m to 420 m below the ground surface. Most of the measurements were performed in ventilation shaft ONK-KU2 and the access tunnel ONK-VT1. Two other locations include the ONK-TKU3 rock mechanics investigation niche at the depth of 345 m level and demonstration tunnels ONK-DT1 and ONK-DT2 at the depth of 420 m level.

Table 4. ONKALO LVDT-measurements 2009 - 2014. (Hakala et al. *2016)*

AZI	DEPTH	QUALITY	LOCALITY	DATE
172	0,343	A	ONK-EDZ PL46 OLKILUOTO	2009
96	0,265	A	ONK-KU2 OLKILUOTO	2009
104	0,204	A	ONK-KU2 OLKILUOTO	2010
155	0,222	A	ONK-KU2 OLKILUOTO	2010
93	0,419	A	ONK-TT4399 PL40 OLKILUOTO	2010
154	0,346	A	ONK-VT1 PL3662 OLKILUOTO	2010
125	0,381	A	ONK-VT1 PL4020 OLKILUOTO	2010
124	0,397	A	ONK-VT1 PL4186 OLKILUOTO	2010
124	0,404	A	ONK-VT1 PL4267 OLKILUOTO	2010
182	0,156	A	ONK-KU2 OLKILUOTO	2011
91	0,349	A	ONK-TKU3-EH3 OLKILUOTO	2011
68	0,418	A	ONK-DT1 PL36 OLKILUOTO	2012
128	0,419	A	ONK-DT2 PL26 OLKILUOTO	2012
92	0,417	A	ONK-DT2 PL96 OLKILUOTO	2012
132	0,315	A	ONK-KU2 OLKILUOTO	2012
166	0,360	A	ONK-KU2 OLKILUOTO	2012
108	0,413	A	ONK-KU2 OLKILUOTO	2013
171	0,340	A	ONK-TKU3 PL46 OLKILUOTO	2014
7	0,340	A	ONK-TKU3 PL61 OLKILUOTO	2014

3.7 Pyhäjoki, Raisio, Sipoo

Suomen Malmi Oy made hydraulic fracturing measurements in August 2009 in Pyhäjoki at a depth of 10 to 27 m. 14 measurements were done using Minifrac System in a 46 mm hole, KR2. Only two measurements (depths of 25.05 m and 26.05 m) were considered successful. In other measurements fractures made impossible to perceive horizontal orientation, because in most cases there were at least three developed fractures instead of aimed two. As an example, in addition to successful two fractures developed third fracture close to second fracture. Based on successful results the major horizontal stress is about 7 MPa and the minor horizontal stress is about 4 MPa. The major horizontal stress direction is about 120 to 300 degrees and on the grounds of four most successful measurements: 125 degrees with standard deviation of 13 degrees. The new data for WSM and Q-WSM was prepared (see Row 102 Appendix 1). (Kivinen & Varis 2009a)

Suomen Malmi Oy made hydraulic fracturing measurements in Raisio in January 2001 at a depth of 5 to 22 m. 30 measurements were done using Minifrac System in three 38 mm holes SK3H, SK4H and SK5H. 11 measurements were considered successful. Rock in SK3H+SK4H is rough-grained mudstone granite and in SK5H mica gneiss/ amphibolite. The new data for WSM and Q-WSM was prepared (see Rows 23-25 Appendix 1). (Mononen 2001a)

Suomen Malmi Oy made hydraulic fracturing measurements in Sipoo Nikkilä in December 2000 at a depth of 5 to 20 m. 20 measurements were done using Minifrac System in two 38 mm holes HM1 and HM2. 11 measurements were considered successful. (See Rows 9-10 Appendix 1) (Mononen 2000d)

3.8 Tampere

The first rock stress measurement in Tampere was made during the planning of Hervanta icehall in the beginning of the 1980's. It pointed the direction of stress field NNE-SSW, but the dispersion was great. That is why directions of the project was evaluated primarily according to geological factors like stone structure, fractures and topography, and secondary according to stress measurements. Rock mechanical characteristic indicate big anisotropy in an area.

Second measurement in Tampere was done for a parking garage in 2008. Suomen Malmi Oy made hydraulic fracturing measurements in two holes, JMT1 and JMT3, in Tampere central area during July in 2008. From 22 measurements 21 succeeded making possible to calculate horizontal direction. The new data for WSM and Q-WSM was prepared (see Rows 91-92 Appendix 1). (Kivinen & Varis 2008)

Third measurement, hydraulic fracturing, in Tampere was done in Tampere tunnel in 2012. Suomen Malmi Oy made hydraulic fracturing measurements in three 56 mm holes, JTM-201, JTM-202 JA JTM-203, in Tampere tunnel during October in 2012. From 30 measurements 23 succeeded making possible to calculate horizontal direction. The new data for WSM and Q-WSM was prepared (see Rows 124-126 Appendix 1). (Tarvainen 2012)

Hydraulic fracturing measurements in Central sewage treatment plant was done from year 2014 to year 2016. The central sewage treatment plant wants to publish measurements only after the construction has finished.

Table 5. New rows with part of information from Turku and Tampere to World Stress Map.

AZI	TYP	DEP	QUA	LOCALITY	DAT	NR	SD	S1	S2
300	HF	0,021	C	KAKOLANMAKI JTM1 TURKU	2003	6	13	17,8	9,0
274	HF	0,024	C	KAKOLANMAKI JTM2 TURKU	2003	7	12	17,1	8,6
267	HF	0,020	E	KAKOLANMAKI JTM3 TURKU	2003	10	59	11,7	5,9
86	OC	0,017	D	KAKOLANMAKI JTM4 TURKU	2003	3	5	20,4	7,6
270	HF	0,020	C	P-HAMPPI JTM1 TAMPERE	2008	9	15	7,6	4,9
265	HF	0,021	D	P-HAMPPI JTM3 TAMPERE	2008	9	44	8,2	5,2
93	HF	0,022	D	TUNNEL JTM-201 TAMPERE	2012	4	26	6,3	3,6
-	HF	0,013	E	TUNNEL JTM-202 TAMPERE	2012	2	-	5,1	3,3
110	HF	0,020	E	TUNNEL JTM-203 TAMPERE	2012	1	-	5,8	3,6

Table 6. Part of information from Turku and Tampere to Quantitative World Stress Map.

Location	Hole	Depth	SigH	Sigh	SigH	Sigh	Method	Year
		metre	MPa	MPa	degree	degree		
TAMPERE TUNNEL	JTM-201	14,7	4,05	2,59	**70,0**	260,0	HF	2012
"	"	19,3	7,53	4,22	**110,0**	280,0	"	"
"	"	21,8	6,08	3,66	90,0	310,0	"	"
"	"	24,5	9,41	4,83	**70,0**	220,0	"	"
"	"	26,3	11,14	5,84	100,0	280,0	"	"
"	"	28,5	6,21	3,62	130,0	330,0	"	"
"	"	29,5	4,09	2,60	**120,0**	300,0	"	"
"	JTM-202	11,8	6,86	4,20	40,0	280,0	"	"
"	"	15,0	3,29	2,47	120,0	240,0	"	"
"	JTM-203	12,6	2,32	2,06	100,0	295,0	"	"
"	"	18,8	1,60	1,96	-	-	"	"
"	"	19,7	2,46	1,81	**110,0**	300,0	"	"
"	"	20,6	8,10	4,80	210,0	350,0	"	"
"	"	29,5	3,09	2,43	-	-	"	"
"	"	30,5	6,82	4,15	-	-	"	"
P-HAMPPI TAMPERE	JTM1	12,8	2,5	2,0	275,0	80,0	HF	2008
"	"	13,6	7,4	5,1	285,0	95,0	"	"
"	"	14,3	10,5	6,8	260,0	105,0	"	"
"	"	14,8	6,2	4,0	245,0	75,0	"	"
"	"	18,4	3,1	3,0	275,0	95,0	"	"
"	"	22,9	12,2	6,9	290,0	115,0	"	"
"	"	23,4	8,6	5,5	255,0	105,0	"	"
"	"	26,3	7,6	5,0	275,0	95,0	"	"
"	"	27,1	10,1	6,0	275,0	110,0	"	"
P-HAMPPI TAMPERE	JTM3	15,6	2,5	2,0	335,0	155,0	HF	2008
"	"	16,1	7,4	5,1	275,0	115,0	"	"
"	"	17,8	10,5	6,8	240,0	35,0	"	"
"	"	20,7	6,2	4,0	-	95,0	"	"
"	"	21,4	3,1	3,0	260,0	90,0	"	"
"	"	21,7	12,2	6,9	250,0	35,0	"	"
"	"	22,1	8,6	5,5	185,0	65,0	"	"
"	"	22,6	7,6	5,0	-	-	"	"
"	"	23,0	10,1	6,0	320,0	140,0	"	"
"	"	23,6	12,2	6,9	260,0	50,0	"	"
"	"	24,9	8,6	5,5	305,0	185,0	"	"
"	"	25,8	7,6	5,0	265,0	80,0	"	"
"	"	26,8	10,1	6,0	220,0	50,0	"	"
KAKOLANMAKI TURKU	JMT1	14,4	-	-	-	-	HF	2003

"	"	15,6	12,3	7,1	285,0	110,0	**Log(P)**	"
"	"	15,6	13,9	7,6	285,0	110,0	**dt/dPvsP**	"
"	"	18,0	17,5	8,7	285,0	110,0	**Log(P)**	"
"	"	18,0	18,0	8,9	285,0	110,0	**dt/dPvsP**	"
"	"	18,8	18,1	9,1	320,0	150,0	**Log(P)**	"
"	"	18,8	18,9	9,4	320,0	150,0	**dt/dPvsP**	"
"	"	21,0	19,0	9,3	310,0	135,0	**Log(P)**	"
"	"	21,0	19,7	9,6	310,0	135,0	**dt/dPvsP**	"
"	"	26,0	19,0	9,8	300,0	130,0	**Log(P)**	"
"	"	26,0	21,1	10,5	300,0	130,0	**dt/dPvsP**	"
"	"	27,0	17,5	9,0	300,0	120,0	**Log(P)**	"
"	"	27,0	19,1	9,5	300,0	120,0	**dt/dPvsP**	"
KAKOLANMAKI TURKU	**JMT2**	19,8	13,3	6,9	285,0	120,0	**Log(P)**	**2003**
"	"	19,8	14,5	7,2	285,0	120,0	**dt/dPvsP**	"
"	"	21,6	16,2	8,2	280,0	105,0	**Log(P)**	"
"	"	21,6	16,9	8,4	280,0	105,0	**dt/dPvsP**	"
"	"	22,5	16,2	8,5	250,0	80,0	**Log(P)**	"
"	"	22,5	18,5	9,2	250,0	80,0	**dt/dPvsP**	"
"	"	24,0	18,4	9,1	280,0	105,0	**Log(P)**	"
"	"	24,0	18,5	9,1	280,0	105,0	**dt/dPvsP**	"
"	"	25,0	15,3	8,0	270,0	90,0	**Log(P)**	"
"	"	25,0	17,3	8,6	270,0	90,0	**dt/dPvsP**	"
"	"	27,1	16,0	8,0	270,0	105,0	**Log(P)**	"
"	"	27,1	16,2	8,1	270,0	105,0	**dt/dPvsP**	"
"	"	28,2	21,2	10,6	285,0	105,0	**Log(P)**	"
"	"	28,2	21,4	10,7	285,0	105,0	**dt/dPvsP**	"
KAKOLANMAKI TURKU	**JMT3**	13,0	11,9	5,9	45,0	195,0	**Log(P)**	**2003**
"	"	13,0	12,4	6,0	45,0	195,0	**dt/dPvsP**	"
"	"	14,4	11,9	6,1	345,0	165,0	**Log(P)**	"
"	"	14,4	12,9	6,4	345,0	165,0	**dt/dPvsP**	"
"	"	16,0	12,1	6,1	285,0	105,0	**Log(P)**	"
"	"	16,0	12,9	6,4	285,0	105,0	**dt/dPvsP**	"
"	"	17,2	12,8	6,4	300,0	150,0	**Log(P)**	"
"	"	17,2	13,6	6,7	300,0	150,0	**dt/dPvsP**	"
"	"	21,1	11,3	5,8	225,0	105,0	**Log(P)**	"
"	"	21,1	12,3	6,1	225,0	105,0	**dt/dPvsP**	"
"	"	22,3	13,5	6,8	340,0	165,0	**Log(P)**	"
"	"	22,3	13,9	7,0	340,0	165,0	**dt/dPvsP**	"
"	"	23,7	9,1	4,9	330,0	195,0	**Log(P)**	"
"	"	23,7	10,6	5,4	330,0	195,0	**dt/dPvsP**	"
"	"	24,9	10,1	5,4	195,0	50,0	**Log(P)**	"
"	"	24,9	11,6	5,9	195,0	50,0	**dt/dPvsP**	"
"	"	26,0	8,4	4,6	45,0	220,0	**Log(P)**	"
"	"	26,0	10,6	5,4	45,0	220,0	**dt/dPvsP**	"
"	"	27,2	9,8	5,1	20,0	240,0	**Log(P)**	"

"	"	27,2	11,4	5,6	20,0	240,0	dt/dPvsP	"
KAKOLANMAKI TURKU	JMT4	15,4	18,9	6,3	92,0	182,0	CSIRO HI	2003
"	DIP 90	16,5	19,3	8,1	85,0	355,0	"	"
"	"	17,4	23,1	8,4	82,0	352,0	"	"

3.9 Turku

There have been only two measurement places in Turku. The first measurement was done in Varissuo in 1980. Suomen Malmi Oy made Leeman overcoring measurements in Varissuo (With 1980). Results from five measurement holes is prepared for Q-WSM (see Rows Appendix 3). The second measurement was done in Kakolanmäki sewage treatment plant in 2003.

Suomen Malmi Oy made hydraulic fracturing measurements in Kakolanmäki In November and December 2003 in three holes, JMT1, JMT2 and JMT3, at a depth of 13 to 28 m. 23 measurements succeeded from 30 making possible to calculate horizontal orientation. Magnitudes were calculated using both Log(P) and dt/dP vs P. The data in WSM was updated (see Rows 33-35 Appendix 1) and new data for Q-WSM was prepared (see Rows 684-730 Appendix 2). (Majapuro 2003a)

Suomen Malmi Oy made three overcoring measurements in Kakolanmäki in November 2003 in one hole, JMT4. The data in WSM was updated (see Row 36 Appendix 1) and new data for Q-WSM was prepared (see Rows 28-30 Appendix 3). (Majapuro 2003b)

3.10 Vantaa

Suomen Malmi Oy has done hydraulic fracturing measurements in Vantaa Finnish Transport Agency Kehärata planning area in October 2008 to February 2009 in five 46 mm holes, SK51, SK63, SK65, SK72 and SK84, at a depth of 8 to 28 m. 26 measurements succeeded from 36 making possible to calculate horizontal orientations and in 29 measurements it was possible to calculate horizontal magnitudes. Results were calculated both using tensile strength from ((Pr1+Pr2+Pr3)/3) and alternatively using tensile strength defined in laboratory. The alternative results are about two times larger than primary results, reasoning real results being somewhere between two results (See Rows 93-97 Appendix 1). (Varis & Kivinen 2009)

4 Database update

One of the goals of the work is to get more quality data to WSM according to newest quality ranking version 2008. The significant factor in WSM classification is a depth of measurement. The majority of measurements have been done under a depth of 30 m, usually with hydraulic fracturing. There are not many new deep measurement places but mostly new measurements at already known deep measurement locations. New measurement locations are mostly for new civil engineering projects, which need information only from local stress state. Measurements for those near surface locations qualify in WSM to lowest quality, because WSM data is aimed for the most part to analyse deeper stress patterns and the interpretation of geodynamic processes

In addition to the depth, quality ranking takes account of standard deviation of maximum horizontal stress. Better than 25% standard deviation can get quality ranking from A to C, when worse than 25% standard deviation get always lower quality ranking, D or E.

New update data is from year 1997 to year 2016. Totally about 1400 new measurements were done in almost 200 measurement holes at a depth of 4 to 1430 m. About 150 new data records is being transferred to WSM. LVDT is being used in 25 data rows, other overcoring technique in 32 data rows and hydraulinc fracturing method in 92 data rows. Most measurements were done for civil engineering purposes. The major horizontal stress as a function of depth in all collected data, new and old, in about 2000 measurements, can be seen in Figure 30, and specified according to old and new overcoring and hydraulic fracturing measurement methods in Figure 31.

The quality of the analyzed about 150 new data records vary from classes A to E and split mostly to class D. All measurements have been done using either LVDT, overcoring or hydraulic fracturing methods, which all are classified in WSM as mainly surface technique. Because of that, class C is possible only with a depth of over 30 m as if all measurements were worse than standard deviation under 25%. The ranking result is always Class E, if a standard deviation is over 40%.

Although in 1992 WSM included only about 1500 stress orientation determinations from Europe, Europe's three distinct regional patterns were already in sight. Scandinavia is a regional area with a WNW-ESE major horizontal orientation. (Müller *et al.* 1992).

Central and essential parameter in rock mechanical analyzes is the stress orientation. World Stress Map (WSM) database is planned as a main interest the orientation of global and regional stress fields. New update data to WSM includes almost 150 stress orientations. The average direction of maximum horizontal stress is about NW-SE although an average standard deviation is quite high.

The stress state of the bedrock increases respect to depth. McGarr (1980) supposes that stress state increases linear. Rock type have an influence how fast stress state increases regarding depth. McGarr (1980) and Engelder (1993) point that stress state increases faster in plutonic rocks and slower in porous stones like sediment stones. One of the reasons, why Q-WSM has been planned, is to collect an information about stress state in different depths and rock types, to know lithologies with depth (Zoback *et al.* 1989). Old WSM data is usually lacking rock type data, because it is not needed earlier. New update tries to improve the situation and restock, where possible, lithologies to old data to make old data more valuable than before. The new rock stress database, Q-WSM, emphasize the importance of knowing precise rock type. Further research should specify used rock types for Finnish data records to integrate results. One of the development points is a uniform terminology for rock types in data records. I trust that rock types will be included systemically to future stress state measurements.

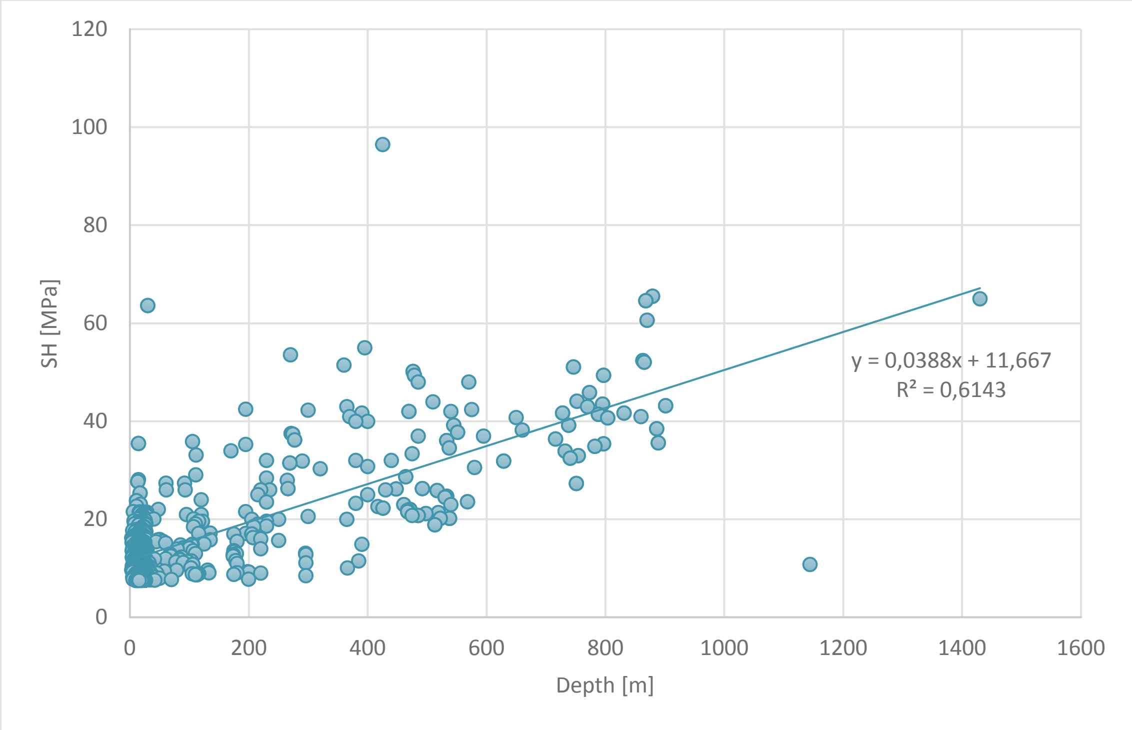

Figure 30. The major horizontal stress as a function of depth in all collected data.

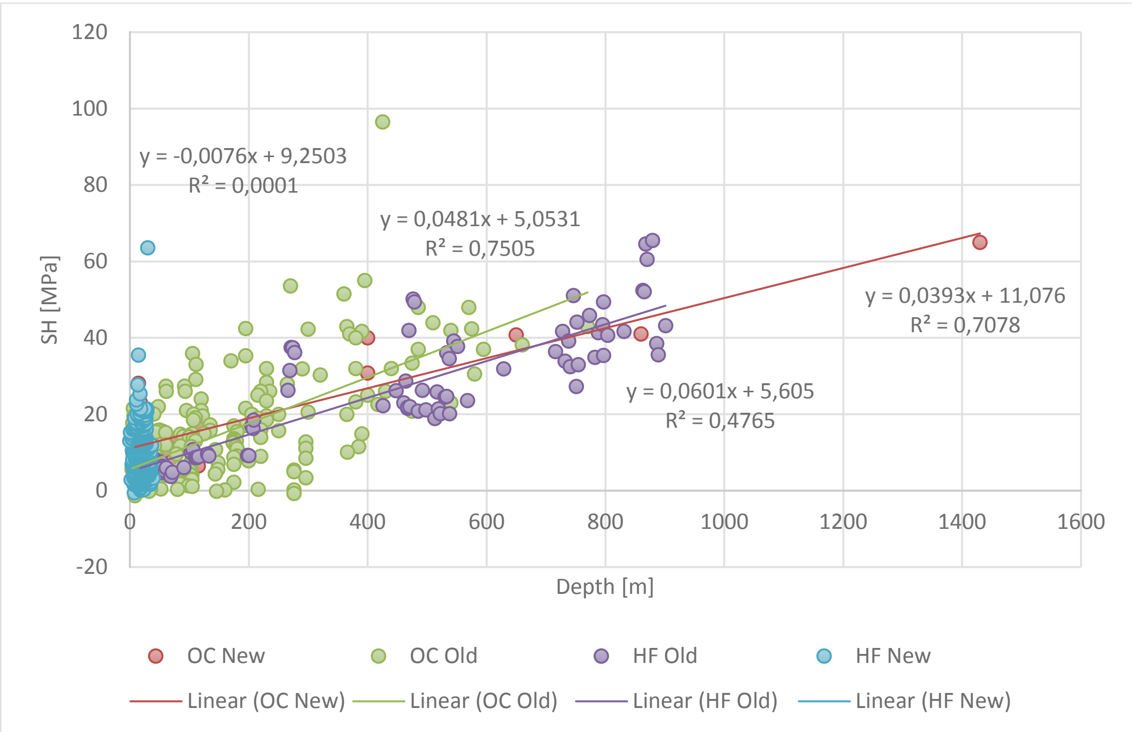

Figure 31. The major horizontal stress as a function of depth in all collected data, over 2000 measurements.

In addition, because the rock in reality is not continuous, homogeneous, isotropic and linear elastic, a grade or a critique of anisotropy of rock type could be expressed better in data notes of stress reportss, because it is possible, that Q-WSM will develop further. One of the suggestions for further research is to collect an anisotropy estimation among other stress measurements information.

LVDT method has not got own quality rankings while yet under overcoring method quality rankings, but it is very likely, that it will get more appreciation in the long run. One of the suggestions for further research is that new method LVDT should be taken in consideration separately from other overcoring when doing quality rankings in WSM, especially when LVDT is used deeper underground situations.

Probably one of the most important suggestions for further research is to collect rock stress measurements more often, preferably every three to five years, at least. Because of bankrupts and many other reasons stress reports can be hard to find, if too much time has passed.

5 Conclusions

The project to update Finnish *in situ* rock stress data in World Stress Map has done a remarkable effort in collecting measurement reports of last 20 years to get about 150 new compiled data records to database based on about 1400 separate measurements. Most measurements were done for civil engineering purposes to find local stress states, but many new deep measurements have been compiled also. Most measurements for civil engineering purposes are located in large cities and thus in about the same locations as in old measurements locations, but World Stress Map database get over two times more data records from Finland as there is without the update.

New measurements are mainly counted as a low quality because of near surface depth of measurements in quality ranking of World Stress Map. Most rock stress measurements were done with hydraulic fracturing, which is normally used in drilled holes at a depth of 30 m or less. Near-surface rock stress measurements do not help in analyses of deep rock stress patterns and the interpretation of geodynamic processes. There has been some over 100 m below ground rock stress measuments in mines, but beside of mines, the most noteworthy over 100 m below ground rock stress measurements have been done in Olkiluoto area, which is the best known underground rock research area in Finland and the final disposal site of spent nuclear fuel. Although stress state deeper from surface is about the same in large areas, more deep measurements in other parts of Finland would be needed to get Finland more usable as a point of view of the tectonic stress field at mid-crustal depths.

New update fine-tune earlier graph of the major horizontal stress as a function of depth. The shift from earlier (Tolppanen & Johansson 1996 ;Tolppanen & Särkkä 1999) is though only a minor (Figure 30). Overall major horizontal stress direction of the new update data follow moderately the regional west-northwest direction of Finland.

The update connects Finland as a partner in cooperation to develop the Quantitative World Stress Map database, which is at present under development. To help developing that new second database, it is important to systematically pay attention to lithology data in rock stress measurements. In earlier rock stress measurement data information about lithology is often hard to find. Beside lithology, more information than before will be collected together with stress magnitude to support future research through the new database.

Different uncertainties in measurements and dispersion of data worsen the possibility to get valuable stress measurements. New and improved rock stress measuring methods and equipment raise the quality of information and enable successful deep rock stress measurements. New LVDT-method has been developed to solve earlier problems and inaccuracies, and provide decent quality in different demands. With competent equipment is possible to get usable rock stress data also in deep rock state.

References

Aaltonen, I. (Ed.). (2016). Geology of Olkiluoto (POSIVA Report 2016-16). Eurajoki, Finland: Posiva Oy. ISBN 978-951-652-244-2

Amadei, B. & Stephansson, O. (1997). *Rock stress and its measurement.* London, United Kingdom. Chapman & Hall. ISBN 0412447002

Anderson, E. M. (1951). "The Dynamics of Faulting and Dyke Formation with Application to Britain. Edinburgh, Great Britain: Oliver & Boyd.

Andersson, J., Ahokas, H., Hudson, J., Koskinen, L., Luukkonen, A., Löfman, J., … Ylä-Mella, M. (2007). *Olkiluoto Site Description 2006* (POSIVA Report 2007-3). Eurajoki, Finland: Posiva Oy. ISBN 978-951-652-151-3

Becker, F. (2015). *Hydraulic fracturing stress measurements in borehole OTN-1* (Activity Report incl. Overview-Plots of Test Records). Espoo, Finland: St1 Deep Heat Ltd.

Brown, E. T., Hoek, E. (1978). Trends in relationships between measured in situ stresses and depth (Technical Note). *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, 15*, 211–215.

Christiansson, R., & Hudson, J. A. (2003). Suggested Methods for rock stress estimation—Part 4: Quality control of rock stress estimation. *International Journal of Rock Mechanics and Mining Sciences, 40*, 1021-1025. doi:10.1016/j.ijrmms.2003.07.004

Cronvall, T. (1994) *Anisotropian huomioiminen kallion jännitystilamittauksissa*, Master's thesis. Espoo, Finland: Helsinki University of Technology.

Engelder, T. (1993). Stress regimes in the lithosphere. Princeton: Princeton University Press.

Gehör, S., Kärki, A., Suoperä, S. & Taikina-aho, O. (1997). *Eurajoen Olkiluodon kairausnäytteen OL -KR9 petrologia ja matalan lämpötilan rakomineraalit* (Posiva Working Report 97-09). Helsinki, Finland: Posiva Oy.

Geologia.fi –internet site (2017). Retrieved June 7, 2017, from http://www.geologia.fi/index.php/2011-12-21-12-30-30/2011-12-21-12-39-11/2011-12-21-12-39-38/suomen-kallioperae

Haimson, B. C., & Cornet, F. H. (2003). ISRM Suggested Methods for rock stress estimation Part 3: hydraulic fracturing (HF) and/or hydraulic testing of pre-existing fractures (HTPF). *International Journal of Rock Mechanics and Mining Sciences, 40*, 1011-1020. doi:10.1016/j.ijrmms.2003.08.002

Hakala, M. (2006). *Quality Control for Overcoring Stress Measurement Data* (Posiva Report 2006-03). Eurajoki, Finland: Posiva Oy. ISBN 951-652-126-6

Hakala, M. & Heine, J. (2014). *In Situ Stress Measurement with LVDT-cell in TP3, Level 400* (Measurement Report). Kemi, Finland: Outokumpu Chrome Oy.

Hakala, M. & Heine, J. (2015). *In Situ Stress Measurement with LVDT-cell in VT5Kup1 at Level 860* (Measurement Report). Kemi, Finland: Outokumpu Chrome Oy.

Hakala, M., Heine, J. & Siren, T. (2016). *In situ jännitystilamittauswith LVDT-kennolla Hakaniemen asemalla* (Measurement Report). Kemi, Finland: Outokumpu Chrome Oy.

Hakala, M. & Tolppanen, P. (2002). Kampin keskuksen irtikairausjännitystilamittausten tulkinta (Measurement Report 2209). Helsinki, Finland: Gridpoint Finland Oy.

Hakala, M., Tolppanen, P., & Ojala, J. (2005). Bedrock stress field in the Satakunta region. Espoo, Finland: Geological Survey of Finland.

Hakala, M., Kemppainen, K., Sirén, T., Heine, J., Christiansson, R., Martin, C. D., & Koskinen, T. (2012, May 25-28). Experience with a new LVDT-Cell to measure in-situ stress from an existing tunnel. In Eurock 2012 Symposium Conference Paper. Stockholm, Sweden: Swedish National Group of ISRM & BeFo – Swedish Rock Engineering Research Foundation.

Hakala, M., Siren, T., Kemppainen, K., Christiansson, R. & Martin, D. (2013). *In situ Stress Measurement with the New LVDT-Cell – Method Description and Verification* (POSIVA Report 2012-43). ISBN 978-951-652-223-7

Hakala, M., Siren, T., Ström, J., Valli, J., Hakala, V., Heine, J., … Savunen, J. (2016) In Situ Stress Measurements in ONKALO with LVDT – Cell (POSIVA Report 2016-20). Eurajoki, Finland: Posiva Oy. ISBN 978-951-652-263-3 / ISSN 2343-4740

Hayashi, K., & Haimson, B. C. (1991). Characteristics of shut-in curves in hydraulic fracturing stress measurements and determination of in situ minimum compressive stress. *Journal of Geophysical Research, 96*(B11). 18311–18321. doi:10.1029/91JB01867

Heidbach, O., Reinecker, J., Tingay, M., Müller, B., Sperner, B., Fuchs, K., Wenzel, F. (2007). Plate boundary forces are not enough: Second- and third-order stress patterns highlighted in the World Stress Map database. *Tectonics, 26*(6), TC6014. doi:10.1029/2007tc002133

Heidbach, O., & Höhne, J. (2008). CASMI - a tool for the visualization of the World Stress Map data base. *Computers and Geosciences, 34*(7), 783-791. doi:1016/j.cageo.2007.06.004

Heidbach, O., Rajabi, M., Reiter, K., Ziegler, M. (2008). *World Stress Map 2008 ; GFZ.* WSM Database Details. Retrieved from http://dc-app3-14.gfz-potsdam.de/pub/release_2008/statistics.html

Heidbach, O., Tingay, M., Barth, A., Reinecker, J., Kurfeß, D. & Müller, B. (2010). Global crustal stress pattern based on the World Stress Map database release 2008. *Tectonophysics 482*, 3-15. doi:10.1016/j.tecto.2009.07.023

Heidbach, O., Rajabi, M., Reiter, K., Ziegler, M. (2016). *World Stress Map 2016; GFZ Data Services.* doi:10.5880/WSM.2016.002

Hudson, J. A., Cornet, F. H., & Christiansson, R. (2003). ISRM Suggested Methods for rock stress estimation Part 1: Strategy for rock stress estimation. *International Journal of Rock Mechanics and Mining Sciences, 40*, 991–998. doi:10.1016/j.ijrmms.2003.07.011

Hudson J. A. & Harrison, J. (1997). *Engineering rock mechanics : an introduction to the principles.* Oxford, Great Britain: Pergamon. ISBN:0-08-041912-7

Huhta P, Korsman K (2005*). Bedrock stress field in the Satakunta region* (Research Report P 34.4.042). Espoo, Finland: Geological Survey of Finland.

Ihalainen, M. (1998). *Jännitystilamittaukset Helsingin Mellunmäessä* (Measurement Report 2835(225)). Helsinki, Finland: Rakennus Oy Lemminkäinen.

Johansson, E. (1984). *Kallion primäärijännitystila ja sen mittaaminen*. Licentiate thesis. Espoo, Finland: Helsinki University of Technology.

Kim, K. & Franklin, J. A. (Eds.). (1987). ISRM Suggested Methods for rock stress estimation. *International Journal of Rock Mechanics and Mining Sciences, 24*(1), 55-63. doi:10.1016/0148-9062(87)91232-0

Kivinen, A., Varis, K. (2008a). *Jännitystilamittaukset hydraulisen murtuman periaatteella Tampereella 2008* (Measurement Report 225/2839/08/AK,KV). Tampere, Finland: Tampereen pysäköintitalo Oy.

Kivinen, A. & Varis, K. (2008b). *Jännitystilamittaukset hydraulisen murtuman periaatteella Helsingissä 2007* (Measurement Report 114/1802/08/KV/AK). Helsinki, Finland: Suomen Malmi Oy.

Kivinen, A., Varis, K. (2008c). *Jännitystilamittaukset hydraulisen murtuman periaatteella Espoossa 2008* (Measurement Report 225/2819/08/AK,KV). Espoo, Finland: City of Espoo.

Kivinen, A. & Varis, K. (2009a). *Jännitystilamittaukset hydraulisen murtuman menetelmällä Pyhäjoella 2009* (Measurement Report 223/2934 III/09/AK,KV). Pyhäjoki, Finland: Fennovoima Oy.

Kivinen, A. & Varis, K. (2009b). *Jännitystilamittaukset hydraulisen murtuman menetelmällä Helsingin Lauttasaaressa 2009* (Measurement Report 223/2907/09/AK,KV). Helsinki, Finland: Suomen Malmi Oy.

Kivinen, A. & Varis, K. (2009c). *Jännitystilamittaus hydraulisen murtuman menetelmällä Mikkelissä 2009* (Measurement Report 223/2940/09/AK,KV). Mikkeli, Finland: Suomen Malmi Oy.

Kivinen, A. & Varis, K. (2010a). *Jännitystilamittaukset hydraulisen murtuman menetelmällä Espoon Tapiolassa 2010* (Measurement 223/2024/10/AK,KV). Espoo, Finland: Suomen Malmi Oy.

Kivinen, A. & Varis, K. (2010b). *Jännitystilamittaukset hydraulisen murtuman menetelmällä Espoon Blominmäessä 2010* (Measurement 223/2025/10/AK,KV). Espoo, Finland: Suomen Malmi Oy.

Klasson, H. (2000). *Kalliojännitystilamittaukset Helsingin Salmisaaressa* (Measurement Report 1136300). Helsinki, Finland: Swedpower Ab.

Kukkonen, I. (2011). *Outokumpu Deep Drilling Project 2003-2010.* ISBN 978-952-217-152-8

Kukkonen, I. (2017, February 13-15). Personal communication about ongoing research.

Lehtinen, M. Nurmi, P.A. Rämö, O.T. (2005). *Precambrian geology of Finland : key to the evolution of the Fennoscandian shield.* Amsterdam : Elsevier.

Ljunggren, C. & Andersson, S. (1998) *Overcoring rock stress measurements in borehole R1/98, Espoo* (Measurement Report). Espoo, Finland: City of Espoo.

Majapuro, J. (2003a). *Jännitystilamittaus hydraulisella murtamisella Kakolanmäen kalliopuhdistamossa (*Measurement Report 114/1352/03/JM). Turku, Finland: Suunnittelukeskus Oy.

Majapuro, J. (2003b). *Jännitystilamittaus irtikairausmenetelmällä Kakolanmäen kalliopuhdistamossa (*Measurement Report 114/1352/03/JM). Turku, Finland: Suunnittelukeskus Oy.

Majapuro, K. (2003c). *Jännitystilamittaus hydraulisella murtamisella Kluuvin maanalainen sähköasema (*Measurement Report 114/1361/03/JM). Helsinki, Finland: Helsingin energia.

Majapuro, J. (2004a). *Jännitystilamittaus Helsingin City Centerissä 10 – 11.2.2004 (.* Measurement Report 114/1408/04/JM). Helsinki, Finland: Koy Helsingin Kaivokatu 8.

Majapuro, K. (2004b). *Jännitystilamittaus Vuosaaressa 26.2.2004 – 5.4.2004 (*Measurement Report 114/1415/04/JM*).* Helsinki, Finland: City of Helsinki.

Majapuro, K. (2004c). *Jännitystilamittaus Vallilassa 20.7.2004 – 21.7.2004 (*Measurement Report 114/1454/04/JM). Helsinki, Finland: SRV Teräsbetoni Oy.

Majapuro, J. (2004d). *Jännitystilamittaus Kumpulassa joulukuussa 2004 (*Measurement Report 225/2451/04/JM). Helsinki, Finland: JP-Suoraplan Oy.

Majapuro, J. (2005a). *Simpsiönvuoren liikuntahalli jännitystilamittaus hydraulisella murtamisella (*Measurement Report 225/2506/05/JM). Lapua, Finland: Kalliosuunnittelu Oy.

Majapuro, J. (2005b). *Jännitystilamittaus Kampissa irtikairausmenetelmällä 10 – 24.02.2005 (*Measurement Report 225/2510). Helsinki, Finland: SRV Teräsbetoni Oy.

Majapuro, J. (2005c). *Jännitystilamittaus hydraulisella murtamisella Mäkkylässä 8.12.2005 – 12.12.2005 (*Measurement Report 225/2527/05/JM). Espoo, Finland: Tieliikennelaitos.

Majapuro, J. (2005d). *Jännitystilamittaus irtikairaamalla Meilahden sairaalan alueen mittausten yhteydessä (*Measurement Report 225/2525/05/JM). Helsinki, Finland: Kalliosuunnittelu Oy Rockplan Ltd.

Majapuro, J. (2006a). *Jännitystilamittaus hydraulisen murtamisen menetelmällä Olkiluodossa 9.1.2006 – 1.2.2006 (*Measurement Report 225/2605). Eurajoki, Finland: Teollisuuden Voima Oyj.

Majapuro, J. (2006b). *Jännitystilamittaus irtikairausmenetelmällä Olkiluodossa 16.3.2006 – 7.4.2006 (*Measurement Report 225/2605). Eurajoki, Finland: Teollisuuden Voima Oyj.

Malmlund, H. & Johansson, E. (2002). *Jännitystilan tarkastelu Posiva Oy:n tutkimusalueilla (*Working Report 2002-47). Eurajoki, Finland: Posiva Oy.

McGarr, A. (1980). Some constraints on levels of shear stress in the crust from observation and theory. *Journal of Geophysical Research: Solid Earth, 85*(B11), 6231-6238. doi: 10.1029/JB085iB11p06231

Mononen, S., Hakala, M. & Mikkola, P. (2001). *Kallioperän jännitystilan mittaaminen : laitekehityshankkeen valmisteluvaihe* (Research Report 31). Espoo, Finland: Helsinki University of Technology, Laboratory of Rock Mechanics. TKK-KAL-A-32. ISBN 951-22-6874-4 ISSN 1239-6788.

Mononen, S. (2000a). *Jännitystilamittaukset hydraulisella murtamisella Helsingin Kampissa* (Measurement Report 225/2553/00/SM). Helsinki, Finland: HKR-Rakennuttaja.

Mononen, S. (2000b). *Jännitystilamittaukset CSIRO HI-kennoa käyttäen Salmisaaren hiilitunnelissa maanalaisen kivihiilivaraston kalliotutkimuksiin liittyen vuonna 2000* (Measurement Report 225/2541 II/00/SM). Helsinki, Finland: Helsingin Energia.

Mononen, S. (2000c). *Jännitystilamittaukset hydraulisella murtamisella Salmisaaren hiilitunnelissa maanalaisen kivihiilivaraston kalliotutkimuksiin liittyen vuonna 2000* (Measurement Report 225/2540/00/SM). Helsinki, Finland: Helsingin Energia.

Mononen, S. (2000d). *Jännitystilamittaukset hydraulisella murtamisella Sipoon Nikkilässä* (Measurement Report 225/2554). Sipoo, Finland: City of Sipoo.

Mononen, S. (2000e). *Jännitystilamittaukset hydraulisella murtamisella Espoon Tapiolan Hakalehdossa* (Measurement Report 225/2540/00/SM). Espoo, Finland: City of Espoo.

Mononen, S. (2001a). *Jännitystilamittaukset hydraulisella murtamisella Raision Haunisessa* (Measurement Report 224,225,227/2609/01/SM). Raisio, Finland: Oy Radiolinja Ab.

Mononen, S. (2001b). *Jännitystilamittaukset luonnontieteellisen museon maanalaisten kokoelmatilojen tutkimusten yhteydessä Arkadiankadulla Helsingissä* (Measurement Report 114/224/1619/2610/01/SM). Helsinki, Finland: University of Helsinki.

Mononen, S. (2002). *Kampin keskuksen jännitystilamittaus hydraulisella murtamisella* (Measurement Report 2209). Helsinki, Finland: SRV Teräsbetoni Oy.

Mononen, S. (2003a). *Kallioperän rakennettavuus – jännitystilan mallinnus* (Research Report 32). Espoo, Finland: Helsinki University of Technology, Laboratory of Rock Mechanics. TKK-KAL-A-32. ISBN 951-22-6874-4 ISSN 1239-6788.

Mononen, S. (2003b). *Jännitystilamittaukset hydraulisella murtamisella Leppävirralla reiässä SK11* (Measurement Report 22.1.2003). Espoo, Finland: Helsinki University of Technology.

Mononen, S. (2003c*). Jännitystilamittaukset hydraulisella murtamisella Stockmann / kasvu-projektiin liittyvä Mannerheimintien pysäköintilaitoksen kalliotutkimuksissa tutkimusrei'issä JTM-1, JTM-2 ja JTM-3 helmi – huhtikuussa 2003 (*Measurement Report 114/1322/03/SM). Helsinki, Finland: Stockmann Oyj Abp.

Mononen, S. (2003d*). Jännitystilamittaukset hydraulisella murtamisella Stockmann / kasvu-projektiin liittyvä Mannerheimintien pysäköintilaitoksen kalliotutkimuksissa tutkimusrei'issä JTM-201 ja JTM-202 maalis – toukokuussa 2003 (*Measurement Report 114/1326/03/SM). Helsinki, Finland: Stockmann Oyj Abp.

Mononen, S. (2003e). *Jännitystilamittaukset hydraulisella murtamisella Vuosaaressa* (Measurement Report 114/1309 III/03/SM). Helsinki, Finland: Tiehallinto.

Mononen, S. (2005*). Jännitystilan huomioon ottaminen rakennuskiven louhinnassa (*Research report). Espoo, Finland: Helsinki University of Technology.

Mononen, S. (2005). *Rock mechanical analyses of in situ stress / strength ratio at the Teollisuuden Voima Oy investigation sites Kivetty, Olkiluoto and Romuvaara.* Licentiate thesis. Espoo, Finland: Helsinki University of Technology.

Müller, B., Zoback, M. L., Fuchs, K., Mastin, L., Gregersen, S., Pavoni, N., Ljunggren, C. (1992) Regional patterns of tectonic stress in Europe. *Journal of Geophysical Research, 97*(B8), 11783–11803. doi:10.1029/91JB01096

Nironen, M. (Ed.). (2017). Bedrock of Finland at the scale 1:1 000 000 - Major stratigraphic units, metamorphism and tectonic evolution (Special Paper). Espoo, Finland: Geological Survey of Finland. 978-952-217-380-5 (pdf); 978-952-217-379-9 (paperback)

Palmström, A. & Singh, R. (2001). *The deformation modulus of rock masses - Comparisons between in situ tests and indirect estimates*. doi: 10.1016/S0886-7798(01)00038-4

Posiva Oy. (2006). *Quality Control for Overcoring Stress Measurement Data* (Research Report POSIVA 2006-03). Eurajoki, Finland: Author. ISBN 951-652-126-6 ISSN 1239-3096

Posiva Oy. (2009). *Olkiluoto Site Desctiption* (Research Report POSIVA 2009-01). Eurajoki, Finland: Author. ISBN 978-951-652-169-8 ISSN 1239-3096.

Rantanen, T. (2013). *Effect of overcoring induced heat on LVDT stress measurements*, Master's thesis. Helsinki, Finland: Aalto University.

Rautio, T. (2002). *Kampin keskuksen jännitystilamittaus irtikairausmenetelmällä* (Measurement Report). Helsinki, Finland: SRV Teräsbetoni Oy.

Rummel, F. (1986). Stresses and tectonics of the upper continental crust, a review. In O. Stephansson (Ed.), *Rock stress and rock stress measurements 1986. Proceedings of the International Symposium on Rock Stress and Rock Stress Measurements in Stockholm (*pp. 177–186). Luleå, Sweden: Centek publishers.

Sarwade, D.V., Mishra, K.K., Kapoor, V.K. & Kumar, N. (2009, December). Stress Measurement in Rock Mass. In *Indian Geotechnical Conference Contributory Papers* (pp. 233-237). Indian Geotechnical Society, Guntur, India: Allied Publishers Pvt. Ltd. ISBN 9788184245448.

Savage, W.Z., Swolfs, H.S. & Amadei, B. (1992). On the state of stress in the near surface of the Earth's crust. *Pure and Applied Geophysics, 138,* 207-228. doi:10.1007/BF00878896

Sheorey, P. R. (1994). A theory of in-situ stress in isotropic and transversely isotropic rock. *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts. 31*(1). 23-34. doi:10.1016/0148-9062(94)92312-4

Sjöberg, J., Christiansson, R., & Hudson, J. A. (2003). ISRM Suggested Methods for rock stress estimation Part 2: overcoring methods. *International Journal of Rock Mechanics and Mining Sciences, 40*, 999–1010. doi:10.1016/j.ijrmms.2003.07.012

Sperner, B., Muller, B., Heidbach, O., Delvaux, D., Reinecker, J., Fuchs, K. (2003) Tectonic stress in the Earth's crust: advances in the World Stress Map project. In D.A. Nieuwland (Ed.), *New insights into structural interpretation and modelling* (Special Publication 212) (pp. 101–116). London, Great Britain: Geological Society.

Stephansson, O. (Ed.). (1986). *Rock stress and rock stress measurements 1986. Proceedings of the International Symposium on Rock Stress and Rock Stress Measurements in Stockholm.* Luleå, Sweden: Centek publishers.

Stephansson, O., Dahlström, L-O., Bergström, K., Myrvang, A., Fjeld, O.K., Hanssen, T.H., Särkkä, P. & Väätäinen, A. (1987). *Fennoscandian Rock Stress Data Base - FRSDB. Research Report TULEA 1987:06.* Sweden: Luleå University.

Stephansson, O., Särkkä, P. & Myrvang, A. (1986). State of stress in Fennoscandia. In O. Stephansson (Ed.), *Rock stress and rock stress measurements 1986. Proceedings of the International Symposium on Rock Stress and Rock Stress Measurements in Stockholm (*pp. 21-32). Luleå, Sweden: Centek publishers.

Stephansson, O., & Zang, A. (2012). ISRM Suggested Methods for Rock Stress Estimation—Part 5: Establishing a Model for the In Situ Stress at a Given Site. *Rock Mechanics and Rock Engineering, 45*(6), 955–969. doi:10.1007/s00603-012-0270-x

Stephansson, O. (2016). *New Data and Update of Fennoscandian Rock Stress Data for WSM and Q-WSM.*

Ström, J. (2009). *Maanalaisten kalliotilojen suunnittelu - siirtymät ja muodonmuutokset* (Master's thesis). Helsinki University of Technology, Finland.

Tarvainen, A.-M. (2008). *Jännitystilamittaus irtikairausmenetelmällä: Helsinki City Spa 22.8. – 4.9.2008* (Measurement Report 225/2835/08/AT). Helsinki, Finland: SRV Viitoset Oy.

Tarvainen, A-M. (2012). *Tampereen tunnelin jännitystilareikien JTM-201, JTM-202 ja JTM-203 tutkimukset hydraulisen murtuman menetelmällä syksyllä 2012* (Measurement report 6023). Tampere, Finland: Saanio & Riekkola Oy.

Tarvainen, A-M. (2013a). *Länsimetron jännitystilareikien JT-10, JT-11 ja JT-17 tutkimukset hydraulisen murtuman menetelmällä 2013* (Measurement report 6026/D/2013/AT). Espoo, Finland: City of Espoo.

Tarvainen, A-M. (2013b). *Länsimetron jännitystilareikien JT-12 - JT-14 tutkimukset hydraulisen murtuman menetelmällä 2013* (Measurement report 3005/I/2013/AT). Espoo, Finland: City of Espoo.

Tarvainen, A-M. (2013c). *Länsimetron jännitystilareiän JT-15 tutkimukset hydraulisen murtuman menetelmällä 2013* (Measurement report 3005 /K/2013/JK,VT). Espoo, Finland: City of Espoo.

Tarvainen, A-M. (2013d). *Länsimetron jännitystilareikien JT-1 - JT-3 sekä JT-18 – JT-19 tutkimukset hydraulisen murtuman menetelmällä 2013* (Measurement report 6026 /A/2013/AT). Espoo, Finland: City of Espoo.

Tarvainen, A-M. (2013e). *Länsimetron jännitystilareikien JT-4 - JT-6 sekä JT-20 tutkimukset hydraulisen murtuman menetelmällä 2013* (Measurement report 6026 /B/2013/AT). Espoo, Finland: City of Espoo.

Tarvainen, A-M. (2013f). *Länsimetron jännitystilareikien JT-7 - JT-9 sekä JT-21 tutkimukset hydraulisen murtuman menetelmällä 2013* (Measurement report 6026 /C/2013/AT). Espoo, Finland: City of Espoo.

Tarvainen, A-M. (2013g). *Länsimetron jännitystilareikien JT-22 - JT-25 tutkimukset hydraulisen murtuman menetelmällä 2013* (Measurement report 6026 /G/2013/AT). Espoo, Finland: City of Espoo.

Tiensuu, K., Kivinen, A., Tarvainen, A.-M., & Varis, K. (2011). OL4:n jännitystilamittaus hydraulisen murtuman menetelmällä Eurajoen Olkiluodossa 2010 – 2011 (Measurement Report 223/2106). Eurajoki, Finland: Teollisuuden Voima Oyj.

Thiercelin MJ, Plumb RA (1994) Core-based prediction of lithologic stress contrasts in East Texas formations. SPE Form Eval Pap SPE 21847:251–258

Tolppanen, P (1996) *Jännitystilan huomioonottaminen rakennuskiven louhinnassa*. Licentiate thesis. Espoo, Finland: Helsinki University of Technology.

Tolppanen, P & Johansson, E (1996) Rock stress measurements in Finland (*Jännitystilamittaukset Suomessa vuosina 1961 – 1994.* Teknologiahanke kalliorakentaminen 2000 in Finnish). The technology program “Rock Engineering 2000” research subreport, project 6.4. 25-41 p. Helsinki, Finland: RIL.

Tolppanen, P., & Särkkä, P. (1999). Quality classification of the Finnish rock stress measurements. In *2nd Euroconference on WSM Deformation and Stress in the Earth's Crust 22. -26.1999.* Abstract*. Sweden: The ÄspöHard Rock Laboratory (HRL).*

Tolppanen, P. J., Johansson, E. J. W., Riekkola, R., & Salo, J. P. (1998). Comparison of vertical and horizontal deposition hole concept for disposal of radioactive waste based on rock mechanical in situ stress-strength analyses. *Engineering Geology, 49*(3–4), 345–352. doi:10.1016/S0013-7952(97)00066-5

Varis, K. (2006). *Jännitystilamittaus kairanreiästä JTM-1 Kauppakartanolla lokakuussa 2006* (Measurement Report 225/2637/06/KV). Helsinki, Finland: City of Helsinki.

Varis, K. (2007a). *Jännitystilamittaukset P-Flemarin pysäköintilaitosta varten keväällä 2007* (Measurement Report 114/1702/07/KV). Turku, Finland: Varma.

Varis, K. (2008a). *Jännitystilamittaukset hydraulisen murtuman periaatteella Länsimetron suunnittelualueella Espoossa 2007* (Measurement Report 114/1768/08/KV.). Helsinki, Finland: Suomen Malmi Oy.

Varis, K. (2008b). *Jännitystilamittaukset hydraulisen murtaman periaatteella Naantalissa 2008* (Measurement Report 225/2816/08/KV). Espoo, Finland: Suomen Malmi Oy.

Varis, K. (2008c). *Jännitystilamittaukset hydraulisen murtaman periaatteella Helsingin Meilahdessa 2008* (Measurement Report 225/2813/08/KV). Helsinki, Finland: Suomen Malmi Oy.

Varis, K. & Kivinen, A. (2008). *Jännitystilamittaukset hydraulisella murtamisella Helsinki City Spa vuonna 2008 (*Measurement Report 225/2835/08/KV,AK). Helsinki, Finland: SRV Viitoset Oy.

Varis, K. & Kivinen, A. (2009). *Jännitystilamittaukset hydraulisen murtuman periaatteella Kehäradan tutkimusalueella 2008 – 2009 (*Measurement Report 223/2902/09/KV,AK). Vantaa, Finland: Pöyry.

Varis, K. & Kivinen, A. (2014). *Jännitystilamittaukset hydraulisella murtamisella Kalasataman kallioparkissa vuonna 2014 (*Measurement Report 6111/2014/AK,KV). Helsinki, Finland: SRV Rakennus Oy.

Varis, K. & Sipola, V. (2006). *Jännitystilamittaus kairanreiästä 3012 Vallikalliolla syyskuussa 2006* (Measurement Report). Espoo, Finland: Tieliikennelaitos.

Varis, K. & Tarvainen, A-M. (2008). *Jännitystilamittaukset irtikairausmenetelmällä Meilahdessa 20.2 – 17.3.2008* (Measurement Report 225/2813 II), reiät JMT-5 ja JMT-6. Helsinki, Finland: Sito.

Vuorimiesyhdistys in Finnish (the Finnish Association of Mining and Metallurgical Engineers). (1981). Rock stress measurements in Finland (Jännitystilamittaukset Suomessa in Finnish). Research Serie A, N.o. 64. Helsinki: Vuorimiesyhdistys – Bergmannaföreningen r.y.

Väätäinen, A. (1988). *Measurement of rock stress in deep boreholes.* Vuorimiesyhdistys. A81. Helsinki : Vuorimiesyhdistys.

Väätäinen, A. (1988). *Kallion jännitystilan mittaus syvissä porarei'issä*. Licentiate thesis. Espoo, Finland: Helsinki University of Technology.

With, E. (1980). *Varissuo* (Measurement Report). Turku, Finland.

Zang A., Stephansson O. (2010). *Stress Field of the Earth's Crust.* doi:10.1007/978-1-4020-8444-7

Zang A, Stephansson O, Heidbach O, Yoon J-S and M Ziegler. (2013). *Quantitative World Stress Map with three case studies: Geologic repository, gold mining and deep geothermal energy. 6th International Symposium on in-situ rock stress* - RS2013.20-22 August 2013, Sendai, Japan.

Zang, A., Stephansson, O., Heidbach, O. & Janouschkowetz, S. (2012). *World Stress Map database as a resource for rock mechanics and rock engineering*. Geotechnical and Geological Engineering, 30(3), 625–646. https://doi.org/10.1007/s10706-012-9505-6

Zoback, M. L., Zoback, M. D., Adams, J., Assumpcao, M., Bell, S., Bergman, E. A., … Zhizhin, M. (1989). Global patterns of tectonic stress (Review article). *Nature, 341*, 291-298.

Zoback ML, Zoback MD, Adams J, Assumpcao M, Bell S, Bergman EA, … Zhizhin M (1989) Global patterns of tectonic stress. Review article. Nature 341: 291-298.

Zoback, M. D., Zoback, M. L. (1989). Tectonic stress field of North America and relative plate motions. In D. B. Slemmons, E. R. Engdahl, M. D. Zoback, & D. D. Blackwell (Eds.), *Neotectonics of North America* (Decade of North American Geology Project) (pp. 339–366). Geological Society of America, Boulder, Colorado.

Zoback, M. L. (1992). First- and second-order patterns of stress in the lithosphere: The World Stress Map Project. *Journal of Geophysical Research, 97*(B8), 11703-11728. doi:10.1029/92jb00132

Zoback, M. D., Barton, C. A., Brudy, M., Castillo, D. A., Finkbeiner, T., Grollimund, B., Wiprut, D. J. (2003). Determination of stress orientation and magnitude in deep wells. *International Journal of Rock Mechanics & Mining Sciences, 40*, 1049–1076.

Appendices

Appendix 1. Update for World Stress Map Data. Part of the information in data records.

	LAT	LON	AZI	TYPE	DEPTH	QUAL-ITY	RE-GIME	LOCALITY	DATE	NUM-BER	SD
1	61,650	24,160	88	OC	0,012	C	U	ORIVESI	1995		
2	60,190	24,900	-	OC	0,014	-	U	MEILAHTI HELSINKI	1997	3	
3	60,230	25,000	153	OC		C	U	VIIKINMAKI HELSINKI	1997		
4	60,400	26,000	1	OC	0,300	C	TF	Haestholmen HH-KR6	1998		
5	60,240	25,110	73	OC	0,004	D	U	MELLUNMAKI Rno.1 HELSINKI	1998	4	26
6	60,240	25,110	55	OC	0,004	E	SS	MELLUNMAKI Rno.2 HELSINKI	1998	4	44
7	60,240	25,110	40	OC	0,004	D	SS	MELLUNMAKI Rno.3 HELSINKI	1998	4	38
8	60,170	24,930	135	HF	0,013	C	TF	KAMPPI MP1/2	2000	8	17
9	60,370	25,270	88	HF	0,014	D	TF	NIKKILA SIPOO HM-1	2000	5	18
10	60,370	25,270	100	HF	0,012	D	TF	NIKKILA SIPOO HM-2	2000	6	13
11	63,660	26,050	30	OC	1,350	C	U	PYHASALMI MINE	2000	3	
12	60,165	24,910	88	OC	0,055	C	TF	SALMISAARI JTM1/2/3 HELSINKI	2000	3	-
13	60,165	24,910	159	OC	0,068	C	TF	SALMISAARI JTM1/2/3 HELSINKI	2000	3	-
14	60,165	24,910	95	OC	0,078	C	TF	SALMISAARI JTM1/2/3 HELSINKI	2000	3	-
15	60,165	24,910	46	OC	0,086	C	SS	SALMISAARI JTM1/2/3 HELSINKI	2000	3	-
16	60,165	24,910	119	OC	0,100	C	TF	SALMISAARI JTM1/2/3 HELSINKI	2000	2	-
17	60,165	24,910	142	OC	0,115	C	TF	SALMISAARI JTM1/2/3 HELSINKI	2000	3	-
18	60,165	24,910	130	OC	0,014	D	TF	SALMISAARI JTM4 HELSINKI	2000	3	
19	60,165	24,910	145	HF	0,012	D	TF	SALMISAARI JTM-5/6/7/8 HELSINKI	2000	7	24
20	60,180	24,800	-	HF	0,013	D	TF	TAPIOLA JTM-1/2/4 ESPOO	2000	12	65
21	65,780	24,700	-	OC	0,300	C	TF	KEMIN KAIVOS	2001	2	13
22	65,780	24,700	330	OC	0,553	C	U	KEMIN KAIVOS	2001	2	13
23	60,500	22,100	135	HF	0,014	C	TF	RAISIO HAUNINEN SK3H+SK4H	2001	5	21
24	60,500	22,100	45	HF	0,012	D	TF	RAISIO HAUNINEN UPPER SK5H	2001	3	23
25	60,500	22,100	135	HF	0,020	D	TF	RAISIO HAUNINEN LOWER SK5H	2001	3	6
26	60,170	24,930	80	HF	0,018	D	TF	ARKADIANKATU JTM1/2 HELSINKI	2001	3	26
27	60,170	24,930	83	HF	0,011	D	TF	ARKADIANKATU JTM3 LOWER HELSINKI	2001	2	11
28	60,170	24,930	127	HF	0,020	D	TF	ARKADIANKATU JTM3 DEEPER HELSINKI	2001	5	6

29	60,170	24,930	111	OC	0,018	E	TF	KAMPPI JTM1	2002	1	-
30	60,170	24,930	138	OC	0,018	D	TF	KAMPPI JTM2	2002	5	9
31	60,170	24,930	60	HF	0,017	D	TF	KAMPPI JTM4	2002	2	5
32	60,170	24,930	-	HF	0,007	E	TF	KAMPPI JTM5	2002	2	63
33	60,450	22,240	120	HF	0,021	D	TF	KAKOLANMAKI JTM1 TURKU	2003	6	14
34	60,450	22,240	94	HF	0,024	D	TF	KAKOLANMAKI JTM2 TURKU	2003	7	12
35	60,450	22,240	97	HF	0,020	E	TF	KAKOLANMAKI JTM3 TURKU	2003	10	54
36	60,450	22,240	86	OC	0,017	D	TF	KAKOLANMAKI JTM4 TURKU	2003	3	5
37	60,170	24,950	146	HF	0,015	D	TF	KLUUVI JTM HELSINKI	2003	4	5
38	62,500	27,790	150	HF	0,010	D	TF	LEPPAVIRTA SK9/SK10	2003	2	29
39	62,500	27,790	64	HF	0,010	C	TF	LEPPAVIRTA SK11	2003	6	
40	60,165	24,940	135	HF	0,017	D	TF	STOCKMANN PARKING JTM1/2/3 HELSINKI	2003	21	16
41	60,165	24,940	135	HF	0,017	D	TF	STOCKMANN PARKING JTM201 HELSINKI	2003	1	-
42	60,165	24,940	150	HF	0,019	D	TF	STOCKMANN PARKING JTM202 HELSINKI	2003	3	0
43	62,860	29,330	-E100-E99	OC	0,350		TF	OL-KR24 OLKILUOTO	2003	2	9
44	60,220	25,170	110	HF	0,013	D	TF	VUOSAARI HARBOUR HF1 HELSINKI	2003	2	40
45	60,170	24,940	-	HF	0,010	E	TF	CITY CENTER JTM HELSINKI	2004	4	42
46	60,210	24,960	80	HF	0,020	D	TF	KUMPULA JTM1 HELSINKI	2004	3	9
47	60,210	24,960	120	HF	0,015	D	TF	KUMPULA JTM2 HELSINKI	2004	4	25
48	60,210	24,960	58	HF	0,020	D	TF	KUMPULA JTM3 HELSINKI	2004	4	5
49	60,195	24,960	91	HF	0,017	D	TF	VALLILA JTM1 HELSINKI	2004	6	20
50	60,195	24,960	113	OC	0,014	C	TF	VALLILA HELSINKI	2004	3	16
51	60,220	25,170	350	HF	0,018	D	TF	VUOSAARI TUNNEL JTM1/2 HELSINKI	2004	4	6
52	60,220	25,170	235	HF	0,017	D	TF	VUOSAARI TUNNEL JTM3 HELSINKI	2004	7	25
53	60,170	24,930	26	OC	0,024	D	TF	KAMPPI JTM1	2005	2	18
54	60,170	24,930	154	OC	0,025	E	TF	KAMPPI JTM2	2005	1	-
55	60,190	24,900	78	OC	0,020	D	U	MEILAHTI JTM1/2 HELSINKI	2005	6	
56	60,225	24,825	20	HF	0,010	D	TF	MESTARINTUNNELI 3006/3007 ESPOO	2005	1	-
57	62,960	22,950	70	HF	0,013	D	TF	SIMPSIO JTM1/2 LAPUA	2005	6	25
58	60,207	25,086	123	HF	0,009	E	TF	KAUPPAKARTANO JMT1 HELSINKI	2006	5	38
59	60,225	24,825	120	HF	0,021	D	TF	MESTARINTUNNELI 3012 ESPOO	2006	1	-

60	62,860	29,330	89	HF	0,017	D	TF	OL-3 HF OLKILUOTO	2006	13	32
61	62,860	29,330	93	OC	0,017	D	TF	OL-3 OC OLKILUOTO	2006	3	24
62	60,160	24,750	-	HF	0,014	E	TF	METRO JT501/JT502 MATINKYLA ESPOO	2007	0	-
63	60,175	24,750	2	HF	0,021	D	TF	METRO JT2501 OLARINLUOMA ESPOO	2007	7	14
64	60,175	24,750	42	HF	0,023	D	TF	METRO JT2502 OLARINLUOMA ESPOO	2007	6	24
65	60,172	24,780	18	HF	0,015	D	TF	METRO JT3501 NIITTYMAA ESPOO	2007	9	11
66	60,172	24,780	80	HF	0,019	D	TF	METRO JT3502 NIITTYMAA ESPOO	2007	6	44
67	60,175	24,800	75	HF	0,019	D	TF	METRO JT4501 TAPIOLA ESPOO	2007	6	25
68	60,175	24,800	147	HF	0,023	D	TF	METRO JT4502 TAPIOLA ESPOO	2007	3	25
69	60,190	24,830	118	HF	0,017	D	TF	METRO JT6501 OTANIEMI ESPOO	2007	8	25
70	60,190	24,830	112	HF	0,012	D	TF	METRO JT6502 OTANIEMI ESPOO	2007	8	25
71	60,170	24,830	51	HF	0,018	D	TF	METRO JT7501 KEILANIEMI ESPOO	2007	8	25
72	60,170	24,830	171	HF	0,018	D	TF	METRO JT7502 KEILANIEMI ESPOO	2007	7	25
73	60,163	24,850	33	HF	0,020	D	TF	METRO JT9501 VASKILAHTI HELSINKI	2007	8	25
74	60,160	24,870	69	HF	0,017	D	TF	METRO JT11501/2 LAUTTASAARI HELSINKI	2007	12	40
75	60,190	24,950	95	HF	0,011	E	TF	P-FLEMARI JTM1 HELSINKI	2007	4	65
76	60,190	24,950	161	HF	0,007	D	TF	P-FLEMARI JTM2 HELSINKI	2007	4	31
77	60,165	24,940	113	OC	0,014	D	TF	CITY SPA JTM EROTTAJA HELSINKI	2008	3	16
78	60,165	24,940	300	HF	0,024	C	U	CITY SPA JTM1/2 EROTTAJA HELSINKI	2008	6	
79	60,165	24,940	330	HF	0,021	C	U	CITY SPA JTM3 EROTTAJA HELSINKI	2008	6	
80	65,780	24,700	149	OC	0,450	C	U	KEMI MINE JT1/2	2008	2	13
81	60,190	24,900	292	HF	0,019	E	TF	MEILAHTI JTM3 HELSINKI	2008	8	50
82	60,190	24,900	295	HF	0,018	D	TF	MEILAHTI JTM4 HELSINKI	2008	7	38
83	60,190	24,900	75	OC	0,013	E	U	MEILAHTI JTM5 HELSINKI	2008	1	-
84	60,160	24,750	86	HF	0,017	D	U	METRO JT09/12 MATINKYLA ESPOO	2008	4	
85	60,175	24,800	299	HF	0,023	D	TF	METRO JT34 TAPIOLA ESPOO	2008	8	25
86	60,170	24,800	264	HF	0,018	D	TF	METRO JT36 TAPIOLA ESPOO	2008	9	
87	60,460	22,100	-	HF	0,022	E	TF	NAANTALI TUPAVUORI JTM1	2008	7	64
88	62,860	29,330	-	HF	0,230		TF	OLKKR40/ONK-PP125 OLKILUOTO	2008	2	9
89	62,860	29,330	-	OC	0,230		TF	OLK-PP170 OLKILUOTO	2008	2	9
90	62,860	29,330	-	OC	0,230		TF	OLK-PP68 OLKILUOTO	2008	2	9
91	61,500	23,770	91	HF	0,020	D	TF	P-HAMPPI JTM1 TAMPERE	2008	9	15

92	61,500	23,770	85	HF	0,021	D	TF	P-HAMPPI JTM3 TAMPERE	2008	11	44
93	60,300	24,950	104	HF	0,019	E	TF	KEHARATA SK51 VANTAA	2009	10	47
94	60,300	24,950	104	HF	0,018	D	TF	KEHARATA SK63 VANTAA	2009	4	33
95	60,300	24,950	136	HF	0,022	D	TF	KEHARATA SK65 VANTAA	2009	4	33
96	60,300	24,950	96	HF	0,019	D	TF	KEHARATA SK72 VANTAA	2009	4	25
97	60,300	24,950	105	HF	0,017	E	TF	KEHARATA SK84 VANTAA	2009	4	53
98	60,160	24,870	80	HF	0,021	D	TF	METRO LAUTTASAARI JT381 HELSINKI	2009	5	59
99	61,700	27,400	92	HF	0,022	D	U	METSA-SAIRILA JT1 MIKKELI	2009	13	
100	62,860	29,330	172	LVDT	0,343	A	TF	ONK-EDZ PL46 OLKILUOTO	2009	2	9
101	62,860	29,330	96	LVDT	0,265	A	TF	ONK-KU2 OLKILUOTO	2009	2	9
102	64,470	24,260	125	HF	0,026	D	TF	PYHAJOKI	2009	4	13
103	60,200	24,600	43	HF	0,020	D	TF	BLOMINMAKI JT101 ESPOO	2010	8	18
104	60,200	24,600	54	HF	0,020	D	TF	BLOMINMAKI JT102 ESPOO	2010	8	20
105	60,200	24,600	22	HF	0,018	D	TF	BLOMINMAKI JT103 ESPOO	2010	7	12
106	62,860	29,330	96	HF	0,023	C	TF	OL-4 OLKILUOTO	2010	57	39
107	62,860	29,330	104	LVDT	0,204	A	TF	ONK-KU2 OLKILUOTO	2010	2	9
108	62,860	29,330	155	LVDT	0,222	A	TF	ONK-KU2 OLKILUOTO	2010	2	9
109	62,860	29,330	93	LVDT	0,419	A	TF	ONK-TT4399 PL40 OLKILUOTO	2010	2	9
110	62,860	29,330	154	LVDT	0,346	A	TF	ONK-VT1 PL3662 OLKILUOTO	2010	2	9
111	62,860	29,330	125	LVDT	0,381	A	TF	ONK-VT1 PL4020 OLKILUOTO	2010	2	9
112	62,860	29,330	124	LVDT	0,397	A	TF	ONK-VT1 PL4186 OLKILUOTO	2010	2	9
113	62,860	29,330	124	LVDT	0,404	A	TF	ONK-VT1 PL4267 OLKILUOTO	2010	2	9
114	60,170	24,800	-	HF	0,020	E	TF	TAPIOLA JT-1020 ESPOO	2010	7	65
115	60,170	24,800	-	HF	0,020	E	TF	TAPIOLA JT-1021 ESPOO	2010	7	45
116	62,860	29,330	182	LVDT	0,156	A	TF	ONK-KU2 OLKILUOTO	2011	2	9
117	62,860	29,330	91	LVDT	0,349	A	TF	ONK-TKU3-EH3 OLKILUOTO	2011	2	9
118	60,160	24,710	100/280	HF	0,023		U	METRO SUOMENOJA JT2 ESPOO	2012	2	
119	62,860	29,330	68	LVDT	0,418	A	TF	ONK-DT1 PL36 OLKILUOTO	2012	2	9
120	62,860	29,330	128	LVDT	0,419	A	TF	ONK-DT2 PL26 OLKILUOTO	2012	2	9
121	62,860	29,330	92	LVDT	0,417	A	TF	ONK-DT2 PL96 OLKILUOTO	2012	2	9
122	62,860	29,330	132	LVDT	0,315	A	TF	ONK-KU2 OLKILUOTO	2012	2	9
123	62,860	29,330	166	LVDT	0,360	A	TF	ONK-KU2 OLKILUOTO	2012	2	9

124	61,500	23,750	270	HF	0,022	C	U	RANTATUNNELI JTM-201 TAMPERE	2012	12	28
125	61,500	23,750	290	HF	0,012	C	U	RANTATUNNELI JTM-202 TAMPERE	2012	12	28
126	61,500	23,750	325	HF	0,025	C	U	RANTATUNNELI JTM-203 TAMPERE	2012	12	28
127	62,860	29,330	104	LVDT	0,400	A	TF	KYLYLAHTI MINE	2013	2	9
128	60,150	24,640	80	HF	0,027	D	TF	METRO KIVENLAHTI JT10 ESPOO	2013		
129	60,150	24,640	80	HF	0,031	D	TF	METRO KIVENLAHTI JT11 ESPOO	2013		
130	60,150	24,640	-	HF	0,023	D	U	METRO KIVENLAHTI JT12 ESPOO	2013		
131	60,150	24,640	130	HF	0,021	D	TF	METRO KIVENLAHTI JT13 ESPOO	2013		
132	60,150	24,640	-	HF	0,033	D	TF	METRO KIVENLAHTI JT14 ESPOO	2013		
133	60,150	24,640	-	HF	0,007	D	TF	METRO KIVENLAHTI JT17 ESPOO	2013		
134	60,160	24,610	30	HF	0,025	D	U	METRO SAUNALAHTI JT15 ESPOO	2013	1	-
135	60,160	24,710	65	HF	0,027	D	U	METRO SUOMENOJA JT1 ESPOO	2013		
136	60,160	24,710	0	HF	0,025	D	U	METRO SUOMENOJA JT18 ESPOO	2013	8	25
137	60,160	24,710	-	HF	0,029	D	U	METRO SUOMENOJA JT19 ESPOO	2013		
138	62,860	29,330	108	LVDT	0,413	A	TF	ONK-KU2 OLKILUOTO	2013	2	9
139	60,190	24,980	55	OC	0,015	D	TF	KALASATAMA HELSINKI	2014	2	14
140	65,780	24,700	69,4	LVDT	0,400	B	TF	KEMI MINE	2014	2	13
141	65,780	24,700	104,4	LVDT	0,860	B	TF	KEMI MINE	2014	2	13
142	62,860	29,330	171	LVDT	0,340	A	TF	ONK-TKU3 PL46 OLKILUOTO	2014	2	9
143	62,860	29,330	7	LVDT	0,340	A	TF	ONK-TKU3 PL61 OLKILUOTO	2014	2	9
144	65,780	24,700	127	LVDT	1,430	B	SS	PYHASALMI MINE	2014	2	sd
145	60,180	24,830	-	HFG	1,249	E	SS	DEEP HOLE ST1 ESPOO	2015	-	-
146	60,180	24,950	84	LVDT	0,016	D	TF	HAKANIEMI MP2 HELSINKI	2015	1	13
147	62,860	29,330	121	LVDT	0,650	C	TF	KYLYLAHTI MINE	2015	2	14
148	61,668	27,360	70	HF	0,023	D	TF	MIKKELI JT1 METSA-SAIRILA	2009	7	32
149	61,668	27,360	2	HF	0,021	D	TF	MIKKELI JT2 METSA-SAIRILA	2010	6	18

Appendix 2. Separate hydraulic fracturing measurements usable for the development of Quantitative World Stress Map (Q-WSM). Part of the information in data records.

	SITE	HOLE	DEPTH	SH	Sh	SV	DIR SH	DIR Sh	YEAR	LITHOLOGY
		DIP	m	MPa	MPa	MPa	degree	degree		
1	DEEP HOLE ST1 ESPOO	OTN-1	778,00		13,80	21,0			2015	
2	"	"	923,00		32,00	24,9			2015	
3	"	"	1055,00		36,00	28,5			2015	
4	"	"	1114,00		21,50	30,1			2015	
5	"	"	1225,00		22,60	33,1			2015	
6	"	"	1345,00		39,80	36,3			2015	
7	"	"	1570,00		38,30	42,4			2015	
8	"	"	1623,00		26,00	43,8			2015	
9	"	"	1720,00		29,20	46,4			2015	
10	ESPOO ESPOONLAHTI	JT-10	17,94	21,53	11,79	0,5	70,0	275,0	2013	
11	"	"	19,18	-	-	0,5	-	-	"	
12	"	"	21,10	14,80	0,48	0,5	65,0	-	"	
13	"	"	22,55	-	-	0,6	-	-	"	
14	"	"	24,39	-	-	0,6	-	-	"	
15	"	"	27,04	4,93	3,48	0,7	100,0	-	"	
16	"	"	32,02	-	-	0,8	-	-	"	
17	"	"	32,89	7,31	5,58	0,9	-	-	"	
18	"	"	33,72	-	-	0,9	-	-	"	
19	"	"	34,93	6,27	3,48	0,9	-	-	"	
20	"	"	36,49	11,93	7,89	0,9	-	280,0	"	
21	ESPOO KIVENLAHTI	JT-11	23,30	-	-	0,6	-	-	2013	
22	"	"	24,80	6,05	4,66	0,6	110,0	260,0	"	
23	"	"	31,60	-	-	0,8	-	-	"	
24	"	"	38,20			1,0	-	-	"	
25	"	"	39,37	3,34	2,88	1,0	-	-	"	

26	**ESPOO KIVENLAHTI**	**JT-17**	3,90	12,24	5,64	0,1	(30)	-	2013	
27	"	"	5,40	-	-	0,1	-	-	"	
28	"	"	6,20	-	-	0,2	-	-	"	
29	"	"	7,30	-	-	0,2	-	-	"	
30	"	"	9,95	-	-	0,3	-	-	"	
31	"	"	10,70	-	-	0,3	-	-	"	
32	**ESPOO SOUKKA**	**JT-7**	6,15	3,54	2,06	0,2	-	-	2013	
33	"	"	17,40	5,18	3,66	0,5	-	-	"	
34	"	"	23,32	8,32	5,36	0,6	-	-	"	
35	"	"	24,53	13,08	6,88	0,6	-	-	"	
36	"	"	26,09	4,64	3,57	0,7	-	-	"	
37	"	"	30,38	6,10	3,54	0,8	-	-	"	
38	"	"	32,13	3,95	3,12	0,8	-	-	"	
39	"	"	32,98	6,62	3,72	0,9	140,0	350,0	"	
40	"	"	33,80	9,24	5,30	0,9	150,0	330,0	"	
41	"	"	34,75	5,85	3,33	0,9	-	330,0	"	
42	"	"	35,55	-	-	0,9	-	-	"	
43	**ESPOO SUOMENOJA**	**JT-8**	16,06	-	-	0,4	-	-	2013	
44	"	"	20,41	7,22	2,10	0,5	-	-	"	
45	"	"	27,91	3,80	0,69	0,7	-	-	"	
46	"	"	31,49	-	-	0,8	-	-	"	
47	"	"	32,83	6,65	0,94	0,9	-	-	"	
48	**ESPOO SOUKKA**	**JT-9**	2,05	2,86	2,07	0,1	-	-	2013	
49	"	"	6,78	1,67	1,32	0,2	-	-	"	
50	"	"	10,40	7,15	3,63	0,3	60,0	240,0	"	
51	"	"	16,20	2,39	2,58	0,4	-	-	"	
52	"	"	25,33	6,35	3,94	0,7	-	-	"	
53	"	"	33,08	3,20	1,63	0,9	-	-	"	
54	"	"	34,70	1,75	1,92	0,9	-	-	"	
55	**ESPOO SOUKKA**	**JT-21**	12,58	3,24	2,42	0,3	30,0	240,0	2013	
56	"	"	14,69	3,32	2,48	0,4	80,0	330,0	"	
57	"	"	19,56	10,05	6,06	0,5	-	230,0	"	

58	"	"	24,15	5,40	3,54	0,6	180,0	350,0	"	
59	"	"	26,14	4,67	3,45	0,7	130,0	290,0	"	
60	**ESPOO SUOMENOJA**	**JT-4**	10,36	3,90	2,98	0,3	-	-	2013	
61	"	"	15,06	4,54	3,34	0,4	140,0	240,0	"	
62	"	"	17,22	-	-	0,4	-	-	"	
63	"	"	18,78	5,90	3,55	0,5	-	-	"	
64	"	"	19,90	-	-	0,5	-	-	"	
65	"	"	21,38	-	-	0,6	-	-	"	
66	"	"	24,44	-	-	0,6	-	-	"	
67	"	"	26,47	-	-	0,7	-	-	"	
68	"	"	28,17			0,7	-	-	"	
69	"	"	29,86	63,62	32,31	0,8	-	-	"	
70	"	"	30,72			0,8	-	-	"	
71	"	"	32,69	-	-	0,8	-	-	"	
72	**ESPOO SUOMENOJA**	**JT-5**	16,07	7,06	4,82	0,4	(110)	240,0	2013	
73	"	"	19,69	8,22	5,17	0,5	-	250,0	"	
74	"	"	20,50	-	-	0,5	-	-	"	
75	"	"	22,58	1,79	4,24	0,6	-	-	"	
76	"	"	24,28	-	-	0,6	-	-	"	
77	"	"	26,48	-	-	0,7	-	-	"	
78	"	"	27,69	-	-	0,7	-	-	"	
79	"	"	28,63	-	-	0,7	-	-	"	
80	"	"	29,40	6,96	4,16	0,8	-	250,0	"	
81	"	"	30,29	5,03	3,04	0,8	-	-	"	
82	"	"	32,01	-	-	0,8	170,0	-	"	
83	**ESPOO SUOMENOJA**	**JT-6**	15,76	21,53	11,79	0,4	-	-	2013	
84	"	"	18,26	-	-	0,5	-	-	"	
85	"	"	19,28	5,92	5,15	0,5	-	270,0	"	
86	"	"	20,16	-	-	0,5	-	-	"	
87	"	"	21,41	-	-	0,6	-	-	"	
88	"	"	22,91	-	-	0,6	-	-	"	
89	"	"	24,08	-	-	0,6	-	-	"	

90	"	"	25,79	4,27	3,99	0,7	150,0	-	"	
91	"	"	28,92	6,27	3,48	0,8	-	230,0	"	
92	"	"	31,96	-	-	0,8	-	-	"	
93	"	"	34,61	-	-	0,9	-	-	"	
94	**ESPOO IIVISNIEMI**	**JT-20**	6,80	6,90	4,64	0,2	-	220,0	2013	
95	"	"	26,75	13,52	7,75	0,7	10,0	190,0	"	
96	"	"	28,75	-	-	0,7	-	-	"	
97	"	"	31,60	9,99	5,25	0,8	30,0	210,0	"	
98	"	"	33,10	9,65	5,28	0,9	40,0	220,0	"	
99	"	"	34,60	10,19	6,18	0,9	-	220,0	"	
100	**ESPOO SUOMENOJA**	**JT-1**	16,49	4,75	2,84	0,4	-	-	2013	
101	"	"	17,44	6,40	3,72	0,5	160,0	-	"	
102	"	"	25,52	-	-	0,7	-	270,0	"	
103	"	"	35,20	2,31	1,86	0,9	-	-	"	
104	"	"	35,75	-	-	0,9	-	-	"	
105	"	"	38,18	-	-	1,0	-	-	"	
106	**ESPOO SUOMENOJA**	**JT-2**	17,10	10,74	6,24	0,4	220,0	330,0	2013	
107	"	"	18,80	5,29	3,35	0,5	-	-	"	
108	"	"	21,50	8,06	4,80	0,6	10/185	280,0	"	
109	"	"	23,30	-	-	0,6	-	300,0	"	
110	"	"	25,75	-	-	0,7	-	-	"	
111	"	"	27,00	-	-	0,7	-	340,0	"	
112	"	"	33,35	-	-	0,9	-	335,0	"	
113	"	"	34,40	7,64	4,71	0,9	90,0	270,0	"	
114	**ESPOO SUOMENOJA**	**JT-18**	14,55	6,48	3,58	0,4	100,0	240,0	2013	
115	"	"	19,25	9,70	4,79	0,5	10,0	180,0	"	
116	"	"	21,10	4,16	2,05	0,5	10	190,0	"	
117	"	"	22,40	3,78	2,06	0,6	0,0	190,0	"	
118	"	"	24,75	6,74	3,64	0,6	350,0	180,0	"	
119	"	"	26,35	8,78	4,91	0,7	350,0	190,0	"	
120	"	"	29,05	5,35	3,38	0,8	30,0	190,0	"	
121	"	"	30,65	6,98	4,17	0,8	150,0	320,0	"	

122	"	"	34,55	5,24	3,13	0,9	170,0	350,0	"	
123	**ESPOO SUOMENOJA**	**JT-19**	27,45	5,51	2,56	0,7	70,0	-	2013	
124	"	"	28,85	-	-	0,8	-	-	"	
125	"	"	30,05	6,18	2,96	0,8	280,0	-	"	
126	"	"	30,85	6,56	3,25	0,8	-	-	"	
127	"	"	32,35	11,14	5,78	0,8	250,0	-	"	
128	"	"	33,75	-	-	0,9	-	-	"	
129	**TAMPERE RANTATUNNELI**	**JTM-201**	14,70	4,05	2,59	0,4	**70,0**	260,0	2012	
130	"	"	19,25	7,53	4,22	0,5	**110,0**	280,0	"	
131	"	"	21,80	6,08	3,66	0,6	90,0	310,0	"	
132	"	"	24,48	9,41	4,83	0,6	**70,0**	220,0	"	
133	"	"	26,25	11,14	5,84	0,7	100,0	280,0	"	
134	"	"	28,50	6,21	3,62	0,7	130,0	330,0	"	
135	"	"	29,50	4,09	2,60	0,8	**120,0**	300,0	"	
136	"	**JTM-202**	11,75	6,86	4,20	0,3	40,0	280,0	"	
137	"	"	15,00	3,29	2,47	0,4	120,0	240,0	"	
138	"	**JTM-203**	12,55	2,32	2,06	0,3	100,0	295,0	"	
139	"	"	18,75	1,60	1,96	0,5	-	-	"	
140	"	"	19,65	2,46	1,81	0,5	**110,0**	300,0	"	
141	"	"	20,63	8,10	4,80	0,5	210,0	350,0	"	
142	"	"	29,50	3,09	2,43	0,8	-	-	"	
143	"	"	30,45	6,82	4,15	0,8	-	-	"	
144	**ESPOO BLOMINMÄKI**	**JT101**	10,57	-	-	0,3	10,0	225,0	2010	
145	"	"	11,83	-	-	0,3	40,0	220,0	"	
146	"	"	14,16	3,05	3,01	0,4	-	-	"	
147	"	"	15,02	3,43	12,52	0,4	45,0	355,0	"	
148	"	"	15,51	2,43	4,95	0,4	25,0	185,0	"	
149	"	"	20,53	-	-	0,5	-	0,0	"	
150	"	"	22,44	-	-	0,6	65,0	305,0	"	
151	"	"	25,55	8,16	6,81	0,7	50,0	215,0	"	
152	"	"	26,67	9,62	3,48	0,7	50,0	335,0	"	
153	"	"	28,67	8,76	3,60	0,7	55,0	225,0	"	

154	**ESPOO BLOMINMÄKI**	**JT102**	10,50	3,27	2,17	0,3	95,0	235,0	2010	
155	"		11,16	4,58	2,47	0,3	-	305,0	"	
156	"	"	13,90	4,74	2,82	0,4	35,0	230,0	"	
157	"	"	15,00	7,29	4,46	0,4	40,0	200,0	"	
158	"	"	16,06	6,53	4,75	0,4	55,0	195,0	"	
159	"	"	20,00	5,60	3,52	0,5	65,0	185,0	"	
160	"	"	24,15	4,65	3,29	0,6	45,0	205,0	"	
161	"	"	25,15	7,36	4,69	0,7	35,0	210,0	"	
162	"	"	26,90	-	-	0,7	-	-	"	
163	"	"	28,60	20,75	11,75	0,7	65,0	230,0	"	
164	**ESPOO BLOMINMÄKI**	**JT103**	9,99	7,56	4,25	0,3	20,0	175,0	2010	
165	"		11,75	4,57	2,75	0,3	20,0	210,0	"	
166	"	"	18,30	7,24	4,29	0,5	35,0	205,0	"	
167	"	"	20,54	-	-	0,5	-	-	"	
168	"	"	21,53	8,27	4,48	0,6	10,0	205,0	"	
169	"	"	22,53	6,51	3,59	0,6	5,0	335,0	"	
170	"	"	23,50	-	-	0,6	35,0	200,0	"	
171	"	"	26,81	6,71	3,38	0,7	30,0	230,0	"	
172	"	"	27,80	7,27	4,18	0,7	-	-	"	
173	**ESPOO TAPIOLA**	**JTM-1020**	12,04	8,61	4,88	0,3	165,0	145,0	2010	
174	"		13,05	13,20	7,80	0,3	75,0	125,0	"	
175	"	"	16,14	4,72	3,66	0,4	5,0	200,0	"	
176	"	"	17,70	10,85	6,95	0,5	95,0	95,0	"	
177	"	"	19,48	12,64	7,32	0,5	155,0	125,0	"	
178	"	"	21,07	4,80	3,36	0,5	-	-	"	
179	"	"	22,70	12,13	7,77	0,6	-	-	"	
180	"	"	24,96	7,91	5,01	0,6	-	-	"	
181	"	"	26,92	11,19	6,34	0,7	5,0	53,0	"	
182	"	"	28,03	9,02	5,50	0,7	45,0	35,0	"	
183	**ESPOO TAPIOLA**	**JTM-1021**	11,17	-	-	0,3	55,0	50,0	2010	
184	"		12,22	10,59	7,05	0,3	45,0	45,0	"	
185	"	"	15,04	2,05	2,58	0,4	65,0	65,0	"	

186	"	"	16,00	11,05	6,18	0,4	115,0	50,0	"	
187	"	"	21,20	-	-	0,6	-	-	"	
188	"	"	22,14	-	-	0,6	-	-	"	
189	"	"	25,30	-	-	0,7	115,0	-	"	
190	"	"	26,05	-	-	0,7	145,0	140,0	"	
191	"	"	27,46	-	-	0,7	-	-	"	
192	"	"	28,78	-	-	0,7	160,0	175,0	"	
193	**OL-4 OLKILUOTO**	**1**	19,01	3,43	2,89	0,5	55,0	275,0	2010-2011	
194	"	"	24,68	5,81	4,10	0,6	75,0	265,0	"	
195	"	"	29,61	7,20	3,85	0,8	105,0	275,0	"	
196	"	"	32,25	6,10	3,49	0,8	65,0	275,0	"	
197	"	**2**	17,06	2,56	2,18	0,4	25,0	255,0	"	
198	"	"	19,71	4,60	3,26	0,5	55,0	215,0	"	
199	"	"	20,41	3,76	2,93	0,5	175,0	-	"	
200	"	**3**	22,83	5,44	3,27	0,6	85,0	245,0	"	
201	"	"	24,10	5,31	3,60	0,6	85,0	285,0	"	
202	"	**4**	17,73	3,84	2,86	0,5	195,0	345,0	"	
203	"	"	21,92	2,69	2,47	0,6	130,0	315,0	"	
204	"	**5**	25,10	5,89	3,46	0,7	125,0	305,0	"	
205	"	"	27,80	6,19	3,90	0,7	85,0	280,0	"	
206	"	**6**	13,06	3,64	2,47	0,3	85,0	275,0	"	
207	"	"	19,28	6,10	3,77	0,5	-	-	"	
208	"	"	31,80	2,83	2,42	0,8	105,0	305,0	"	
209	"	**7**	10,13	2,31	1,88	0,3	115,0	285,0	"	
210	"	"	12,60	4,23	2,47	0,3	115,0	295,0	"	
211	"	"	13,95	5,96	3,16	0,4	55,0	255,0	"	
212	"	"	20,23	10,42	5,32	0,5	125,0	235,0	"	
213	"	**8**	15,64	7,98	4,66	0,4	105,0	275,0	"	
214	"	"	20,27	3,33	2,53	0,5	125,0	255,0	"	
215	"	"	30,83	2,15	1,57	0,8	135,0	315,0	"	
216	"	**9**	20,49	5,12	3,06	0,5	95,0	255,0	"	

217	"	**16**	19,38	2,81	2,07	0,5	85,0	245,0	"	
218	"	"	22,11	2,81	2,07	0,6	85,0	245,0	"	
219	"	"	26,50	3,33	2,32	0,7	80,0	250,0	"	
220	"	**20**	27,71	2,59	2,22	0,7	65,0	235,0	"	
221	"	**21**	14,40	7,02	3,69	0,4	225,0	-	"	
222	"	"	21,80	6,88	3,66	0,6	20,0	185,0	"	
223	"	**22**	29,00	5,54	3,58	0,8	105,0	280,0	"	
224	"	"	31,95	6,51	3,76	0,8	115,0	305,0	"	
225	"	"	33,78	8,88	4,60	0,9	130,0	315,0	"	
226	"	**23**	13,12	2,90	2,47	0,3	95,0	245,0	"	
227	"	"	24,75	7,39	4,64	0,6	85,0	305,0	"	
228	"	"	27,09	5,52	3,66	0,7	85,0	255,0	"	
229	"	"	31,13	8,47	4,74	0,8	105,0	285,0	"	
230	"	**24**	23,88	6,58	4,11	0,6	85,0	275,0	"	
231	"	"	25,10	7,37	3,91	0,7	40,0		"	
232	"	"	30,45	8,66	4,51	0,8	125,0	305,0	"	
233	"	"	34,96	4,87	3,67	0,9	165,0	315,0	"	
234	"	**25**	29,32	5,98	3,11	0,8	105,0	285,0	"	
235	"	"	33,03	5,71	3,61	0,9	85,0	275,0	"	
236	"	"	34,75	6,88	4,26	0,9	125,0	275,0	"	
237	"	**26**	15,13	6,52	3,37	0,4	105,0	285,0	"	
238	"	"	21,05	7,41	4,45	0,5	175,0	355,0	"	
239	"	**29**	12,09	9,02	4,62	0,3	125,0	285,0	"	
240	"	"	13,48	4,96	3,26	0,4	85,0	275,0	"	
241	"	"	14,70	3,52	2,32	0,4	75,0	220,0	"	
242	"	"	21,09	2,84	2,08	0,5	45,0	275,0	"	
243	"	"	25,06	3,37	2,59	0,7	25,0	235,0	"	
244	"	"	31,66	3,06	2,47	0,8	85,0	245,0	"	
245	"	**39**	14,80	9,00	4,78	0,4	85,0	235,0	"	
246	"	"	22,43	7,84	4,06	0,6	105,0	265,0	"	
247	"	**43**	13,00	3,05	1,81	0,3	85,0	255,0	"	
248	"	"	19,74	3,57	2,47	0,5	100,0	285,0	"	

249	"	"	23,75	6,45	3,66	0,6	95,0	280,0	"	
250	"	"	25,33	3,73	2,46	0,7	135,0	295,0	"	
251	**OLKILUOTO**	**ONK-PP169**				0,0			2009	
252	"	**DIP 29,8**				0,0			"	
253	**OLKILUOTO**	**ONK-PP170**	16,29			0,4			2009	
254	"	**DIP 10,5**	18,53			0,5			"	
255	"	"	18,81			0,5			"	
256	**HELSINKI LAUTTASAARI**	**JT381**	14,08	9,53	5,85	0,4	58,0	76,0	2009	Mica gneiss
257	"	"	16,22	-	-	0,4	135,0	147,0	"	Mica gneiss
258	"	"	17,13	-	-	0,4	-	-	"	Granite
259	"	"	20,18	8,35	5,38	0,5	82,0	116,0	"	Granite
260	"	"	22,39	13,69	7,55	0,6	96,0	139,0	"	Granite
261	"	"	24,15	3,97	3,53	0,6	-	-	"	Granite
262	"	"	25,05	9,07	4,71	0,7	-	-	"	Granite
263	"	"	27,03	11,49	7,06	0,7	67,0	50,0	"	Mica gneiss
264	"	"	27,70	-	-	0,7	-	-	"	Mica gneiss
265	"	"	28,79	11,35	6,85	0,7	73,0	82,0	"	Mica gneiss
266	**PYHAJOKI**	**KR2**	11,05	-	-	0,3	20,120	225,300	2009	
267	"	"	11,44	-	-	0,3	110,0	310,200	"	
268	"	"	12,25	2,27	1,96	0,3	45,0	240,0	"	
269	"	"	13,10	12,11	6,60	0,3	-	-	"	
270	"	"	15,14	11,71	6,76	0,4	105,0	255,0	"	
271	"	"	17,66	8,31	5,42	0,5	**130,0**	270 (345-240)	"	
272	"	"	19,14	-	-	0,5	165,0	310,0	"	
273	"	"	20,54	4,81	3,07	0,5	-	-	"	
274	"	"	22,46	9,07	5,12	0,6	-	-	"	
275	"	"	24,46	7,36	4,23	0,6	**120,0**	270 (330-210)	"	
276	"	"	25,05	7,00	3,81	0,7	**110,0**	290,0	"	

277	"	"	25,63	5,24	2,91	0,7	-	-	"	
278	"	"	26,05	5,61	3,38	0,7	**140,0**	310,0	"	
279	"	"	26,48	9,84	5,22	0,7	90,0	330,200	"	
280	**NAANTALI TUPAVUORI**	**JTM1**	15,59	5,92	3,25	0,4	0	350	2008	
281	"	"	16,64	4,00	2,87	0,4	160,0	310	"	
282	"	"	17,39	3,75	2,99	0,5	75,0	240,0	"	
283	"	"	18,00	4,13	2,72	0,5	160,0	290,0	"	
284	"	"	18,54	-	-	0,5	-	-	"	
285	"	"	18,89	-	-	0,5	0,0	120	"	
286	"	"	22,02	-	-	0,6	105,0	290,0	"	
287	"	"	24,34	5,87	3,88	0,6	45,0	230,0	"	
288	"	"	26,99	4,11	3,92	0,7	-	-	"	
289	"	"	28,54	5,50	3,91	0,7	70,0	-	"	
290	**HELSINKI MEILAHTI**	**JTM1**							2005	
291	"								"	
292	"			23,54					"	
293	"	**JTM2**		3,36		50,7			"	
294	"			63,83					"	
295	"								"	
296	"								"	
297	"								"	
298	**HELSINKI MEILAHTI**	**JTM3**	13,07	27,73	13,82	0,3	250,0	50,0	2008	
299	"	"	13,38	15,78	9,02	0,3	260,0	60,0	"	
300	"	"	14,86	15,29	8,55	0,4	230,0	65,0	"	
301	"	"	17,97	-	-	0,5	260,0	90,0	"	
302	"	"	18,33	17,74	9,12	0,5	285,0	120,0	"	
303	"	"	22,40	-	-	0,6	350,0	-	"	
304	"	"	23,92	8,28	5,14	0,6	340,0	175,0	"	
305	"	"	24,88		-	0,6	360,0	135,0	"	
306	**HELSINKI MEILAHTI**	**JTM4**	9,06	8,41	5,39	0,2	270,0	30-210	2008	
307	"	"	11,87	-	-	0,3	240,0	80,0	"	
308	"	"	15,50	15,58	8,08	0,4	350,0	140,0	"	

309	"	"	16,63	14,86	7,98	0,4	300,0	130,0	"	
310	"	"	17,12	7,67	5,26	0,4	270,0	90,0	"	
311	"	"	24,51	8,11	4,76	0,6	330,0	120,0	"	
312	"	"	26,42	8,57	4,94	0,7	310,0	115,0	"	
313	**P-HAMPPI TAMPERE**	**JTM1**	12,83	2,50	2,02	0,3	95,0		2008	mica gneiss
314	"	"	13,55	7,43	5,05	0,4	105,0		"	"
315	"	"	14,33	10,51	6,84	0,4	80,0		"	"
316	"	"	14,77	6,18	3,99	0,4	65,0		"	"
317	"	"	18,35	3,05	2,99	0,5	95,0		"	"
318	"	"	22,85	12,23	6,90	0,6	110,0		"	Migmatite mica gneiss
319	"	"	23,35	8,62	5,54	0,6	75,0		"	"
320	"	"	26,26	7,59	4,98	0,7	95,0		"	"
321	"	"	27,08	10,13	6,03	0,7	95,0		"	"
322	**P-HAMPPI TAMPERE**	**JTM3**	15,58	2,50	2,02	0,4	155,0		2008	Migmatite mica gneiss
323	"	"	16,06	7,43	5,05	0,4	95,0		"	
324	"	"	17,80	10,51	6,84	0,5	60,0		"	
325	"	"	20,70	6,18	3,99	0,5	-		"	
326	"	"	21,36	3,05	2,99	0,6	80,0		"	
327	"	"	21,69	12,23	6,90	0,6	70,0		"	
328	"	"	22,09	8,62	5,54	0,6	5,0		"	
329	"	"	22,55	7,59	4,98	0,6	-		"	
330	"	"	22,95	10,13	6,03	0,6	140,0		"	
331	"	"	23,57	12,23	6,90	0,6	80,0		"	
332	"	"	24,87	8,62	5,54	0,6	125,0		"	
333	"	"	25,75	7,59	4,98	0,7	85,0		"	
334	"	"	26,78	10,13	6,03	0,7	40,0		"	
335	**VANTAA KEHÄRATA**	**SK51**	9,69	11,55	5,30	0,3	120,0	90,0	2008-2009	
336	"		10,94	10,90	5,09	0,3	120,0	115,0	"	
337	"	"	13,70	6,29	3,69	0,4	120,0	105,0	"	
338	"	"	15,42	17,40	7,81	0,4			"	
339	"	"	18,18	4,33	4,99	0,5	45,0	105,0	"	

340	"	"	19,65	-	-	0,5	120,0	160,0	"	
341	"	"	21,73	13,58	5,77	0,6	90,0	110,0	"	
342	"	"	22,61	13,37	5,90	0,6	120,0	105,0	"	
343	"	"	24,70	17,21	6,70	0,6	150,0	150,0	"	
344	"	"	25,58	19,78	7,92	0,7	0,0	150,0	"	
345	"	"	26,25	7,76	3,55	0,7	150,0	140,0	"	
346	**VANTAA KEHÄRATA**	**SK63**	9,30	4,24	3,25	0,2	(0)	(220)	2008-2009	
347	"		11,60	3,47	3,06	0,3	135,0	225,0	"	
348	"	"	12,51	3,81	3,53	0,3	120,0	120,0	"	
349	"	"	19,83			0,5	100,0	145,0	"	
350	"	"	26,73	4,36	3,33	0,7	60,0	60,0	"	
351	**VANTAA KEHÄRATA**	**SK65**	15,12	9,27	6,35	0,4	135,0	310,0	2008-2009	
352	"		16,83	11,79	7,22	0,4	165,0	350,0	"	
353	"	"	18,26			0,5	-		"	
354	"	"	21,16	4,12	2,82	0,6	-		"	
355	"	"	24,30			0,6			"	
356	"	"	25,64			0,7	90,0	270,0	"	
357	"	"	27,36	6,34	4,76	0,7	155,0	315,0	"	
358	"	"	28,14			0,7			"	
359	**VANTAA KEHÄRATA**	**SK72**	10,94	7,90	5,25	0,3	70,0	70,0	2008-2009	
360	"		11,78	7,21	5,43	0,3	95,0	45,0	"	
361	"	"	13,48	10,74	7,03	0,4	90,0	75,0	"	
362	"	"	24,21	6,95	4,10	0,6	130,0	135,0	"	
363	"	"	26,00	8,47	5,18	0,7			"	
364	"	"	26,50	9,65	5,63	0,7			"	
365	**VANTAA KEHÄRATA**	**SK84**	7,69	6,73	4,44	0,2	105,0	330,0	2008-2009	
366	"		8,50	4,95	4,05	0,2	70,0	280,0	"	
367	"	"	23,08	8,51	6,29	0,6	170,0	340,0	"	

368	"	"	23,96	14,31	9,41	0,6	0,0	210,0	"	
369	"	"	26,94	6,88	4,95	0,7			"	
370	**ESPOO MATINKYLA**	**JT09**	15,72	14,03	8,45	0,4	225,0	15,0	2008	
371	"	**JT12**	14,98	3,66	3,11	0,4	210,0	30,0	"	
372	"	"	17,05	8,49	4,95	0,4	230,0	45,0	"	
373	"	"	19,61	11,81	6,82	0,5	210,0	50,0	"	
374	**ESPOO TAPIOLA**	**JT34**	19,42	11,85	6,75	0,5	270,0	105,0	2008	
375	"	"	21,29	3,79	3,70	0,6	315,0	145,0	"	
376	"	"	21,86	12,03	6,56	0,6	195,0	45,0	"	
377	"	"	22,30	8,28	5,44	0,6	310,0	120,0	"	
378	"	"	23,99	12,24	6,70	0,6	315,0	145,0	"	
379	"	"	25,22	16,06	8,95	0,7	325,0	150,0	"	
380	"	"	26,27	11,05	6,52	0,7	315,0	120,0	"	
381	"	"	27,13	11,26	6,10	0,7	345,0	150,0	"	
382	"	"	27,50	6,54	5,39	0,7	-	-	"	
383	**ESPOO TAPIOLA**	**JT36**	12,03	10,79	5,74	0,3	315,0	150,0	2008	
384	"	"	14,48	16,54	8,47	0,4	315,0	90,0	"	
385	"	"	16,40	13,29	7,04	0,4	265,0	80,0	"	
386	"	"	17,69	9,62	5,62	0,5	205,0	35,0	"	
387	"	"	18,27	11,14	5,88	0,5	255,0	120,0	"	
388	"	"	20,10	18,05	9,73	0,5	330,0	150,0	"	
389	"	"	21,90	9,59	5,96	0,6	-	-	"	
390	"	"	22,40	10,83	6,11	0,6	345,0	160,0	"	
391	"	"	22,86	7,17	4,55	0,6	330,0	150,0	"	
392	"	"	23,98	14,91	7,78	0,6	15,0	180,0	"	
393	**HELSINKI SPA**	**JTM1**	20,65	10,64	7,17	0,5	215,0	40,0	2008	
394	"	"	23,02	8,67	6,14	0,6	315,0	130,0	"	
395	"	"	25,69	14,19	9,19	0,7	305,0	115,0	"	
396	"	"	26,60	6,34	5,04	0,7	315,0	145,0	"	
397	"	**JTM1**	13,92	11,16	7,07	0,4	270,0	120,0	"	
398	"	"	15,22	10,43	8,15	0,4	315,0	180,0	"	
399	"	"	17,59	0,20	2,66	0,5	330,0	270,0	"	

400	"	"	23,61	13,99	8,05	0,6	240,0	60,0	"	
401	"	"	24,60	12,36	7,67	0,6	320,0	140,0	"	
402	"	"	27,35	13,68	7,17	0,7	340,0	105,0	"	
403	HELSINKI P-FLEMARI	JTM1	4,35	7,10	4,03	0,1	30,0	200,0	2007	Granite
404	"	"	5,25	10,79	5,44	0,1	-	-	"	Granite
405	"	"	10,43	7,72	4,40	0,3	0,0	330,0	"	Granite
406	"	"	11,05	13,01	6,29	0,3	110,0	340,0	"	Granite
407	"	"	11,70	14,69	8,69	0,3	-	-	"	Granite
408	"	"	13,58	19,56	9,66	0,4	60,0	260,0	"	Granite
409	"	"	15,08			0,4			"	Granite
410	"	"	16,18			0,4			"	Granite
411	"	"	17,28	11,09	6,68	0,4	-	-	"	Granite
412	"	"	18,10	12,28	6,38	0,5	-	-	"	Granite
413	HELSINKI P-FLEMARI	JTM2	6,66	7,22	4,20	0,2	0,0	340,0	2007	Granite
414	"	"	13,29	13,10	6,94	0,3	0,0	180,0	"	Granite
415	"	"	13,93			0,4			"	Granite
416	"	"	14,75	11,77	6,35	0,4	-	-	"	Granite
417	"	"	17,33	12,75	6,66	0,5	-	-	"	Granite
418	"	"	18,04	14,54	7,29	0,5	170,0	330,0	"	Granite
419	"	"	19,28	14,85	7,60	0,5	-	-	"	Granite
420	"	"	20,23	9,37	4,44	0,5	-	-	"	Granite
421	"	"	22,58	14,10	7,30	0,6	115,0	280,0	"	Granite
422	"	"	23,93			0,6			"	Granite
423	ESPOO MATINKYLA	JT501	10,60	7,37	4,67	0,3	-	-	2007	Granite
424	"		12,60	8,35	4,66	0,3	-	-	"	Granite
425	"	"	13,60	6,71	4,06	0,4	-	-	"	Granite
426	ESPOO MATINKYLA	JT502	8,65	2,52	1,77	0,2	-	-	2007	Granite
427	"		10,75	5,94	4,23	0,3	-	-	"	Granite
428	"	"	11,35	5,70	3,83	0,3	-	-	"	Granite
429	"	"	11,85	-	-	0,3	-	-	"	Granite
430	"	"	13,35	7,54	4,47	0,3	-	-	"	Granite
431	"	"	16,60	6,33	3,42	0,4	-	-	"	Granite

432	"	"	17,70	4,89	2,64	0,5	-	-	"	Granite
433	"	"	18,60	-	-	0,5	-	-	"	Granite
434	**ESPOO OLARINLUOMA**	**JT2501**	15,50	7,51	4,41	0,4	0,0	20,0	2007	Granite
435	"		19,25	7,27	4,06	0,5	175,0	165,0	"	Granite
436	"	"	20,00	10,66	5,55	0,5	170,0	160,0	"	Granite
437	"	"	20,95	8,81	4,66	0,5	175,0	165,0	"	Granite
438	"	"	22,25	10,86	5,74	0,6	175,0	175,0	"	Granite
439	"	"	22,65	9,33	5,01	0,6	10,0	0,0	"	Granite
440	"	"	26,20	9,78	5,37	0,7	30,0	20,0	"	Granite
441	**ESPOO OLARINLUOMA**	**JT2502**	13,00	-	-	0,3	165,0	150,0	2007	Granite
442	"		19,85	-	-	0,5	30,0	30,0	"	Granite
443	"	"	20,55	7,90	4,33	0,5	30,0	40,0	"	Granite
444	"	"	21,65	3,20	2,80	0,6	40,0	45,0	"	Granite
445	"	"	22,35	4,21	3,31	0,6	140,0	150,0	"	Granite
446	"	"	23,08	7,37	4,69	0,6	30,0	50,0	"	Granite
447	"	"	25,10	8,47	5,02	0,7	30,0	50,0	"	Granite
448	"	"	25,90	4,47	3,55	0,7	90,0	90,0	"	Granite
449	**ESPOO NIITTYMAA**	**JT3501**	10,50	10,91	5,88	0,3	15,0	20,0	2007	Granite
450	"		11,10	8,07	4,48	0,3	20,0	0,0	"	Granite
451	"	"	11,70	10,92	5,76	0,3	10,0	30,0	"	Granite
452	"	"	12,20	11,86	6,55	0,3	15,0	15,0	"	Granite
453	"	"	13,00	10,86	5,70	0,3	15,0	0,0	"	Granite
454	"	"	13,70	12,21	6,16	0,4	0,0	170,0	"	Granite
455	"	"	15,50	8,73	5,29	0,4	-	-	"	Granite
456	"	"	17,00	13,13	6,65	0,4	40,0	30,0	"	Granite
457	"	"	18,00	12,39	6,65	0,5	30,0	20,0	"	Granite
458	"	"	19,50	10,94	5,93	0,5	20,0	30,0	"	Granite
459	**ESPOO NIITTYMAA**	**JT3502**	12,10	5,64	3,74	0,3	150,0	140,0	2007	Granite
460	"		14,40	4,55	3,25	0,4	130,0	150,0	"	Granite
461	"	"	15,30	10,57	5,58	0,4	-	-	"	Granite
462	"	"	17,15	6,13	3,89	0,4	30,0	40,0	"	Granite
463	"	"	20,80	1,98	1,94	0,5	80,0	60,0	"	Granite

464	"	"	21,30	8,01	4,63	0,6	80,0	90,0	"	Granite
465	"	"	22,80	5,48	3,04	0,6	-	-	"	Granite
466	"	"	24,50	7,59	4,70	0,6	-	-	"	Granite
467	"	"	26,20	10,51	5,67	0,7	60,0	90,0	"	Granite
468	**ESPOO TAPIOLA**	**JT4501**	13,55	14,16	7,36	0,4	110,0	80,0	2007	Migmatic granite
469	"		15,95	19,16	9,77	0,4	100,0	120,0	"	Migmatic granite
470	"	"	19,45	11,77	6,55	0,5	120,0	150,0	"	Migmatic granite
471	"	"	21,00	13,35	7,23	0,5	0,0	20,0	"	Mica gneiss
472	"	"	22,26	12,99	7,18	0,6	60,0	90,0	"	Mica gneiss
473	"	"	23,92	12,60	6,58	0,6	60,0	80,0	"	Mica gneiss
474	**ESPOO TAPIOLA**	**JT4502**	19,70	10,69	5,50	0,5	165,0	165,0	2007	Granite
475	"		20,30	9,86	5,69	0,5	135,0	150,0	"	Granite
476	"	"	21,50	9,09	5,45	0,6	140,0	150,0	"	Granite
477	"	"	22,50	8,35	4,36	0,6	-	-	"	Granite
478	"	"	26,45	10,00	5,58	0,7	-	-	"	Granite
479	**ESPOO OTANIEMI**	**JT6501**	8,00	10,91	5,87	0,2	60,0	100,0	2007	Granite
480	"		8,70	12,11	6,28	0,2	105,0	120,0	"	Granite
481	"	"	9,25	6,05	3,73	0,2	90,0	110,0	"	Granite
482	"	"	9,90	10,63	5,58	0,3	110,0	100,0	"	Granite
483	"	"	11,50	3,43	2,79	0,3	120,0	130,0	"	Granite
484	"	"	18,70	4,31	3,19	0,5	-	-	"	Granite
485	"	"	19,50	12,66	6,72	0,5	150,0	165,0	"	Granite
486	"	"	20,60	9,08	5,09	0,5	175,0	175,0	"	Granite
487	"	"	22,50	15,48	7,65	0,6	-	-	"	Granite
488	"	"	25,50	13,12	6,75	0,7	135,0	150,0	"	Granite
489	**ESPOO OTANIEMI**	**JT6502**	9,00	17,48	8,95	0,2	150,0	135,0	2007	Granite
490	"		9,50	11,40	5,64	0,2	100,0	105,0	"	Granite
491	"	"	10,05	13,86	7,10	0,3	-	-	"	Granite
492	"	"	10,50	3,65	3,04	0,3	100,0	120,0	"	Granite
493	"	"	11,20	12,25	6,43	0,3	60,0	80,0	"	Granite
494	"	"	12,00	3,46	2,75	0,3	90,0	135,0	"	Granite
495	"	"	12,80	7,32	3,95	0,3	150,0	135,0	"	Granite

496	"	"	13,50	6,09	3,47	0,4	130,0	90,0	"	Granite
497	"	"	14,50	9,34	4,74	0,4	-	-	"	Granite
498	"	"	15,50	6,70	3,82	0,4	120,0	140,0	"	Granite
499	**ESPOO KEILANIEMI**	**JT7501**	13,90	12,08	5,87	0,4	30,0	0,0	2007	Mica gneiss
500	"		17,40	4,55	3,23	0,5	30,0	60,0	"	Mica gneiss
501	"	"	18,50	8,77	4,56	0,5	20,0	60,0	"	Mica gneiss
502	"	"	18,90	9,37	4,97	0,5	100,0	120,0	"	Mica gneiss
503	"	"	19,45	9,08	4,69	0,5	30,0	90,0	"	Mica gneiss
504	"	"	20,45	9,23	4,73	0,5	30,0	135,0	"	Mica gneiss
505	"	"	20,95	9,09	4,73	0,5	90,0	50,0	"	Mica gneiss
506	"	"	22,50	9,86	5,25	0,6	60,0	90,0	"	Mica gneiss
507	**ESPOO KEILANIEMI**	**JT7502**	9,50	17,54	9,12	0,2	5,0	-	2007	Mica gneiss
508	"		16,20	12,87	6,56	0,4	175,0	135,0	"	Mica gneiss
509	"	"	17,50	8,58	4,26	0,5	165,0	0,0	"	Mica gneiss
510	"	"	18,40	7,36	4,13	0,5	160,0	170,0	"	Mica gneiss
511	"	"	23,80	8,18	4,10	0,6	10,0	175,0	"	Mica gneiss
512	"	"	26,35	5,33	3,63	0,7	140,0	80,0	"	Mica gneiss
513	"	"	27,45	9,43	4,83	0,7	0,0	10,0	"	Mica gneiss
514	**HELSINKI VASKILAHTI**	**JT9501**	13,20	7,15	4,50	0,3	240,0	60,0	2007	
515	"		16,50	5,97	3,69	0,4	-	15,0	"	
516	"	"	18,00	7,20	4,65	0,5	220,0	40,0	"	
517	"	"	18,90	9,69	5,38	0,5	220,0	50,0	"	
518	"	"	19,50	6,71	4,51	0,5	200,0	40,0	"	
519	"	"	20,00	8,18	4,97	0,5	200,0	30,0	"	
520	"	"	20,40	7,86	4,91	0,5	205,0	30,0	"	
521	"	"	21,00	7,19	4,31	0,5	210,0	50,0	"	
522	"	"	21,50	6,61	4,79	0,6	-	30,0	"	
523	"	"	27,00	3,74	2,78	0,7	210,0	70,0	"	
524	**HELSINKI LAUTTASAARI**	**JT11501**	7,95	4,69	4,00	0,2	300,0	140,0	2007	
525	"		9,05	11,84	6,56	0,2	340,0	240,0	"	
526	"	"	17,40	-	-	0,5	225,0	45,0	"	
527	"	"	18,13	9,61	5,24	0,5	225,0	60,0	"	

528	"	"	20,90	20,95	10,55	0,5	225,0	60,0	"	
529	"	"	21,30	12,32	6,86	0,6	240,0	60,0	"	
530	**HELSINKI LAUTTASAARI**	**JT11502**	14,60	35,51	17,57	0,4	-	-	2007	
531	"		17,00	25,33	15,12	0,4	180,0	330,0	"	
532	"	"	18,90	4,47	5,98	0,5	-	-	"	
533	"	"	20,40	-	-	0,5	250,0	-	"	
534	"	"	22,70	-	-	0,6	255,0	75,0	"	
535	"	"	23,60	-	-	0,6	255,0	120,0	"	
536	"		25,00	-	-	0,7	255,0	75,0	"	
537	"	"	25,60	21,45	11,39	0,7	240,0	90-150	"	
538	**OLKILUOTO-3 HF EURAJOKI**	**JTM-R1**	6,90	3,73	2,42	0,2	45,0	210,0	2006	
539	"	"	6,90	6,30	3,28	0,2	45,0	210,0	"	
540	"	"	8,00	2,68	2,03	0,2	15,0	195,0	"	
541	"	"	8,00	4,96	2,79	0,2	15,0	195,0	"	
542	"	"	9,00	1,83	1,86	0,2	60,0	195,0	"	
543	"	"	9,00	4,79	2,85	0,2	60,0	195,0	"	
544	"	"	21,60	7,60	4,25	0,6	90,0	240,0	"	
545	"	"	21,60	9,33	4,82	0,6	90,0	240,0	"	
546	"	"	24,60	11,02	5,57	0,6	60,0	240,0	"	
547	"	"	24,60	12,84	6,18	0,6	60,0	240,0	"	
548	"	"	25,50	13,78	6,91	0,7	75,0	225,0	"	
549	"	"	25,50	13,79	6,92	0,7	75,0	225,0	"	
550	"	"	27,25	12,30	5,96	0,7	45,0	210,0	"	
551	"	"	27,25	12,38	5,99	0,7	45,0	210,0	"	
552	"	**JTM-R3**	9,70	8,24	4,72	0,3	45,0	225,0	"	
553	"	"	9,70	9,27	5,06	0,3	45,0	225,0	"	
554	"	"	13,50	14,47	7,34	0,4	105,0	300,0	"	
555	"	"	13,50	16,23	7,93	0,4	105,0	300,0	"	
556	"	"	9,50	14,98	7,44	0,2	90,0	315,0	"	
557	"	"	9,50	16,77	8,04	0,2	90,0	315,0	"	
558	"	**JTM-R2B**	23,90	9,91	5,20	0,6	105,0	240,0	"	
559	"	"	23,90	12,63	6,11	0,6	105,0	240,0	"	

560	"	"	25,10	12,38	6,69	0,7	105,0	240,0	"	
561	"	"	25,10	14,34	7,34	0,7	105,0	240,0	"	
562	"	**JTM-R4**	6,80	6,02	3,20	0,2	75,0	240,0	"	
563	"	"	6,80	6,39	3,32	0,2	75,0	240,0	"	
564	"	"	7,85	3,03	2,19	0,2	105,0	225,0	"	
565	"	"	7,85	3,80	2,44	0,2	105,0	225,0	"	
566	"	"	22,60	6,02	3,70	0,6	135,0	360,0	"	
567	"	"		6,51	3,86	0,0	135,0	360,0	"	
568	**HELSINKI KAUPPAKARTANO**	**JTM-1**	4,10	13,69	7,10	0,1	15,0	165,0	2006	Granite
569	"	"	6,38	11,72	6,13	0,2	70,0	240,0	"	Granite
570	"	"	7,22	9,91	5,23	0,2	160,0	280,0	"	Granite
571	"	"	8,76	11,24	5,93	0,2	120,0	315,0	"	Granite
572	"	"	9,53	12,08	6,16	0,2	145,0	310,0	"	Granite
573	"	"	10,66	12,10	5,98	0,3	150,0	340,0	"	Granite
574	"	"	11,14	11,36	6,05	0,3	-	-	"	Granite
575	"	"	13,54	10,87	5,64	0,4	-	-	"	Granite
576	"	"	14,28	9,58	4,92	0,4	-	-	"	Granite
577	"	"	14,97	6,19	3,97	0,4	-	-	"	Granite
578	"	"	4,10	13,67	7,09	0,1	15,0	165,0	"	Granite
579	"	"	6,38	12,57	6,42	0,2	70,0	240,0	"	Granite
580	"	"	7,22	10,81	5,53	0,2	160,0	280,0	"	Granite
581	"	"	8,76	11,49	6,01	0,2	120,0	315,0	"	Granite
582	"	"	9,53	12,46	6,28	0,2	145,0	310,0	"	Granite
583	"	"	10,66	11,30	5,72	0,3	150,0	340,0	"	Granite
584	"	"	11,14	11,93	6,24	0,3	-	-	"	Granite
585	"	"	13,54	9,85	5,30	0,4	-	-	"	Granite
586	"	"	14,28	9,22	4,80	0,4	-	-	"	Granite
587	"	"	14,97	7,31	4,34	0,4	-	-	"	Granite
588	**ESPOO MESTARINTUNNELI**	**3012**	20,61	11,05	6,04	0,5	120,0	300,0	2006	Migmatic granite
589	"	"		9,53	5,53					
590	"	"		9,25	5,21					
591	"	"		10,62	5,67					

592	"	"	133,91	10,90	6,36					
593	"	"	11,16	12,80	6,99					
594	"	"	72,56	13,05	7,21		67,4			
595	"	"	6,05	15,33	7,97		6,7			
596	"	"		14,02	7,28					
597	"	"		16,24	8,02					
598	"	"		4,51	2,79					
599	"	"		6,61	3,49					
600	**ESPOO MESTARINTUNNELI**	**SK-3006**	10,49	2,84	1,69	0,3	20,0	215,0	2005	
601	"	"	10,49	1,45	1,23	0,3				
602	**ESPOO MESTARINTUNNELI**	**SK-3007**	4,85	10,01	5,08	0,1	-	-	2005	
603	"	"	4,85	8,19	4,48	0,1				
604	"	"	8,07	19,10	9,62	0,2	-	-	"	
605			8,07	16,37	8,71	0,2				
606	"	"	11,30	23,77	11,75	0,3	-	-	"	
607	"	"	11,30	22,70	11,40	0,3				
608	"	"	13,85	12,09	7,60	0,4	-	-	"	
609	"	"	13,85	10,28	5,79	0,4				
610	**SIMPSIO LAPUA**	**JTM1**	6,25	10,73	6,33	0,2	45,0	270,0	2005	
611	"	"	6,25	12,87	7,05	0,2	45,0	279,0	"	
612	"	"	13,13	7,77	4,52	0,3	105,0	285,0	"	
613	"	"	13,13	9,40	5,06	0,3	105,0	285,0	"	
614	"	"	18,70	8,26	4,85	0,5	60,0	225,0	"	
615	"	"	18,70	10,63	5,64	0,5	60,0	225,0	"	
616	"	"	19,40	13,25	6,87	0,5	75,0	255,0	"	
617	"	"	19,40	14,56	7,31	0,5	75,0	255,0	"	
618	"	**JTM2**	15,45	11,25	5,91	0,4	15,0	225,0	"	
619	"	"	15,45	13,06	6,51	0,4	15,0	225,0	"	
620	"	"	16,60	12,93	6,73	0,4	15,0	240,0	"	
621	"	"	16,60	13,43	6,89	0,4	15,0	240,0	"	
622	**KUMPULA HELSINKI**	**JTM1**	14,30	12,65	6,37	0,4	75,0	240,0	2004	Amphibolite, grain size 0,5-3mm

623	"	**DIP 90**	14,30	13,36	6,61	0,4	75,0	240,0	"	"
624	"	"	15,20	13,61	7,13	0,4	90,0	270,0	"	"
625	"	"	15,20	15,26	7,68	0,4	90,0	270,0	"	"
626	"	"	26,60	13,15	7,07	0,7	75,0	240,0	"	small pegmatite veins
627	"	"	26,60	15,90	7,99	0,7	75,0	240,0	"	"
628	**KUMPULA HELSINKI**	**JTM2**	8,20	13,51	6,55	0,2	120,0	260,0	2004	Amphibolite, grain size 1-4mm
629	"	"	8,20	14,28	6,81	0,2	120,0	260,0	"	"
630	"	"	11,65	13,21	6,86	0,3	150,0	300,0	"	"
631	"	"	11,65	13,80	7,06	0,3	150,0	300,0	"	"
632	"	"	18,10	12,59	6,89	0,5	90,0	225,0	"	"
633	"	"	18,10	16,18	8,09	0,5	90,0	225,0	"	"
634	"	"	22,45	12,92	7,24	0,6	120,0	285,0	"	"
635	"	"	22,45	17,52	8,78	0,6	120,0	285,0	"	"
636	**KUMPULA HELSINKI**	**JTM3**	16,50	6,87	3,96	0,4	60,0	195,0	2004	Pegmatite, rough-grained 5-30mm
637	"	"	16,50	8,96	4,66	0,4	60,0	195,0	"	Different rock, pegmatite, rough-grained 5-30mm
638	"	"	21,00	6,27	3,38	0,5	50,0	225,0	"	"
639	"	"	21,00	6,92	3,60	0,5	50,0	225,0	"	"
640	"	"	23,40	8,59	4,65	0,6	60,0	255,0	"	"
641	"	"	23,40	9,40	4,92	0,6	60,0	255,0	"	"
642	"	"	24,10	6,56	3,63	0,6	60,0	240,0	"	"
643	"	"	24,10	8,00	4,11	0,6	60,0	240,0	"	"
644	**VALLILA HELSINKI**	**JTM3**	14,14	15,93	8,03	0,4	60,0	225,0	2004	
645	"	"	14,14	16,46	8,21	0,4	60,0	225,0	"	
646	"	"	14,75	17,32	8,70	0,4	90,0	300,0	"	
647	"	"	14,75	18,87	9,22	0,4	90,0	300,0	"	
648	"	"	16,30	20,29	10,31	0,4	110,0	270,0	"	
649	"	"	16,30	21,24	10,63	0,4	110,0	270,0	"	
650	"	"	17,70	11,98	6,26	0,5	75,0	270,0	"	
651	"	"	17,70	13,36	6,82	0,5	75,0	270,0	"	
652	"	"	18,75	10,73	6,19	0,5	105,0	270,0	"	

653	"	"	18,75	12,99	6,94	0,5	105,0	270,0	"	
654	"	"	19,75	11,64	6,20	0,5	105,0	270,0	"	
655	"	"	19,75	14,29	7,08	0,5	105,0	270,0	"	
656	**VUOSAARI TUNNEL HELSINKI**	**JTM1**	13,00	8,51	4,81	0,3	355,0	165,0	2004	quartzfeldspargneiss
657	"	**DIP 90**	13,00	9,27	5,07	0,3	355,0	165,0	"	
658	"	"	16,30	12,25	5,82	0,4	355,0	135,0	"	
659	"	"	16,30	12,92	6,05	0,4	355,0	135,0	"	
660	"	"	22,00	7,77	4,64	0,6	345,0	180,0	"	
661	"	"	22,00	7,95	4,70	0,6	345,0	180,0	"	
662	**VUOSAARI TUNNEL HELSINKI**	**JTM2**	10,70	14,68	7,66	0,3	225,0	30,0	2004	mica gneiss
663	"	"	10,70	16,50	8,27	0,3	225,0	30,0	"	
664	"	"	20,40	10,96	6,25	0,5	345,0	180,0	"	
665	"	"	20,40	12,40	6,73	0,5	345,0	180,0	"	
666	**VUOSAARI TUNNEL HELSINKI**	**JTM3**	14,80	10,60	5,73	0,4	205,0	25,0	2004	limestone
667	"	"	14,80	13,05	6,54	0,4	205,0	25,0	"	
668	"	"	15,25	11,84	5,87	0,4	210,0	20,0	"	
669	"	"	15,25	13,24	6,34	0,4	210,0	20,0	"	
670	"	"	15,80	11,18	5,60	0,4	255,0	90,0	"	
671	"	"	15,80	13,26	6,29	0,4	255,0	90,0	"	
672	"	"	17,40	11,23	6,06	0,5	255,0	90,0	"	
673	"	"	17,40	12,54	6,49	0,5	255,0	90,0	"	
674	"	"	17,90	11,24	5,61	0,5	225,0	75,0	"	
675	"	"	17,90	12,11	5,90	0,5	225,0	75,0	"	
676	"	"	19,40	9,78	5,05	0,5	270,0	105,0	"	
677	"	"	19,40	11,60	5,65	0,5	270,0	105,0	"	
678	**VUOSAARI SATAMA HELSINKI**	**HF-1**	11,00	3,00	2,70	0,3	170,0		2003	
679	"	"	14,90	5,10	4,40	0,4	20,0		"	
680	"	"	15,50	**3,10**	**3,40**	0,4	160,0		"	
681	"	"	17,80	**3,20**	**4,00**	0,5	140,0		"	
682	"	"	21,30	**3,50**	**3,60**	0,6	100,0		"	
683	"	"	23,50	**0,30**	**1,30**	0,6	40,0		"	
684	**KAKOLANMAKI TURKU**	**JMT1**	14,40	-	-	0,4	-	-	2003	Granite

685	"	"	15,60	12,28	7,06	0,4	105,0	110,0	"	Granite
686	"	"	15,60	13,89	7,60	0,4	105,0	110,0	"	Granite
687	"	"	18,00	17,45	8,69	0,5	105,0	110,0	"	Granite
688	"	"	18,00	18,00	8,87	0,5	105,0	110,0	"	Granite
689	"	"	18,80	18,08	9,09	0,5	140,0	150,0	"	Granite
690	"	"	18,80	18,90	9,36	0,5	140,0	150,0	"	Granite
691	"	"	21,00	18,99	9,33	0,5	130,0	135,0	"	Granite
692	"	"	21,00	19,70	9,56	0,5	130,0	135,0	"	Granite
693	"	"	26,00	18,98	9,79	0,7	120,0	130,0	"	Granite
694	"	"	26,00	21,06	10,48	0,7	120,0	130,0	"	Granite
695	"	"	27,00	17,54	9,03	0,7	120,0	120,0	"	Granite
696	"	"	27,00	19,07	9,54	0,7	120,0	120,0	"	Granite
697	**KAKOLANMAKI TURKU**	**JMT2**	19,75	13,33	6,86	0,5	105,0	120,0	2003	Granite
698	"	"	19,75	14,45	7,23	0,5	105,0	120,0	"	Granite
699	"	"	21,60	16,21	8,22	0,6	100,0	105,0	"	Granite
700	"	"	21,60	16,87	8,44	0,6	100,0	105,0	"	Granite
701	"	"	22,50	16,24	8,47	0,6	70,0	80,0	"	Granite
702	"	"	22,50	18,54	9,24	0,6	70,0	80,0	"	Granite
703	"	"	24,00	18,38	9,05	0,6	100,0	105,0	"	Granite
704	"	"	24,00	18,51	9,10	0,6	100,0	105,0	"	Granite
705	"	"	25,00	15,27	7,97	0,7	90,0	90,0	"	Granite
706	"	"	25,00	17,25	8,63	0,7	90,0	90,0	"	Granite
707	"	"	27,10	15,98	8,03	0,7	90,0	105,0	"	Granite
708	"	"	27,10	16,23	8,11	0,7	90,0	105,0	"	Granite
709	"	"	28,20	21,15	10,63	0,7	105,0	105,0	"	Granite
710	"	"	28,20	21,43	10,73	0,7	105,0	105,0	"	Granite
711	**KAKOLANMAKI TURKU**	**JMT3**	13,00	11,87	5,87	0,3	45,0	195,0	2003	Granite
712	"	"	13,00	12,37	6,03	0,3	45,0	195,0	"	Granite
713	"	"	14,40	11,87	6,05	0,4	165,0	165,0	"	Granite
714	"	"	14,40	12,92	6,40	0,4	165,0	165,0	"	Granite
715	"	"	16,00	12,12	6,11	0,4	105,0	105,0	"	Granite
716	"	"	16,00	12,93	6,38	0,4	105,0	105,0	"	Granite

717	"	"	17,20	12,76	6,44	0,4	120,0	150,0	"	Granite
718	"	"	17,20	13,62	6,72	0,4	120,0	150,0	"	Granite
719	"	"	21,10	11,31	5,77	0,5	45,0	105,0	"	Granite
720	"	"	21,10	12,31	6,10	0,5	45,0	105,0	"	Granite
721	"	"	22,30	13,46	6,80	0,6	160,0	165,0	"	Granite
722	"	"	22,30	13,90	6,95	0,6	160,0	165,0	"	Granite
723	"	"	23,70	9,11	4,88	0,6	150,0	195,0	"	Granite
724	"	"	23,70	10,64	5,39	0,6	150,0	195,0	"	Granite
725	"	"	24,90	10,06	5,39	0,6	115,0	50,0	"	Granite
726	"	"	24,90	11,57	5,89	0,6	115,0	50,0	"	Granite
727	"	"	26,00	8,44	4,64	0,7	45,0	220,0	"	Granite
728	"	"	26,00	10,62	5,37	0,7	45,0	220,0	"	Granite
729	"	"	27,20	9,84	5,07	0,7	20,0	240,0	"	Granite
730	"	"	27,20	11,42	5,59	0,7	20,0	240,0	"	Granite
731	**KLUUVI HELSINKI**	**JTM**	13,25	11,72	6,29	0,3	120,0	150,0	2003	granite, medium grain size
732	"		13,25	14,51	7,22	0,3	120,0	150,0	"	
733	"	"	13,75	9,24	5,13	0,4	140,0	0,0	"	
734	"	"	13,75	11,26	5,80	0,4	140,0	0,0	"	
735	"	"	14,25	11,09	5,90	0,4	145,0	10,0	"	
736	"	"	14,25	13,91	6,84	0,4	145,0	10,0	"	
737	"	"	17,10	10,73	5,54	0,4	10,0	150,0	"	
738	"	"	17,10	11,56	5,82	0,4	10,0	150,0	"	
739	**OLKILUOTO**	**OL-KR24**				0,0			2003	
740	**LEPPAVIRTA**	**SK 9**	12,40	20,10	11,80	0,3	90,0		2003	mica gneiss
741	"	**SK 10**	7,40	16,20	8,80	0,2	30-60		"	mica gneiss
742	"	"	7,90	9,50	7,30	0,2	160,0		"	
743	"	"	9,60	6,80	4,30	0,2	150,0		"	
744	"	"	10,20	3,50	3,60	0,3	150,0		"	
745	"	"	12,00	1,30	1,50	0,3	100,0		"	
746	"	**SK 11**	11,05	6,60	4,30	0,3	65,0		"	
747	"	"	12,05	5,60	4,40	0,3	120,0		"	
748	"	"	12,55	2,60	3,50	0,3	140,0		"	

749	"	"	14,85	5,20	3,50	0,4	60,0		"	
750	"	"	16,50	6,90	4,30	0,4	75,0		"	
751	"	"	17,80	2,10	2,10	0,5	50,0		"	
752	"	"	19,40	1,00	2,00	0,5	70,0		"	
753	"	"	21,65	4,00	3,40	0,6	55,0		"	
754	"	"	26,60	8,90	5,20	0,7	80,0		"	
755	"	"	27,85	6,30	3,90	0,7	100,0		"	
756	**HELSINKI CITY CENTER**	**JTM**	4,27	10,49	5,71	0,1	330,0	-	2004	Granite
757	"	"	4,27	13,56	6,73	0,1	330,0	-	"	Granite
758	"	"	5,40	14,50	7,86	0,1	330,0	120,0	"	Granite
759	"	"	5,40	16,06	8,38	0,1	330,0	120,0	"	Granite
760	"	"	15,00	15,44	7,94	0,4	240,0	30,0	"	Granite
761	"	"	15,00	17,71	8,69	0,4	240,0	30,0	"	Granite
762	"	"	16,55	13,61	7,27	0,4	270,0	165,0	"	Granite
763	"	"	16,55	17,03	8,41	0,4	270,0	165,0	"	Granite
764	**STOCKMANN PARKING HEL-SINKI**	**JTM1**	25,43	9,30	6,20	0,7	160,0	-	2003	amphibolite, mica gneiss
765	"	"	21,29	7,30	5,00	0,6	160,0	-	"	amphibolite, mica gneiss
766	"	"	20,61	4,70	6,90	0,5	-	-	"	granite
767	"	"	19,71	11,90	6,90	0,5	-	-	"	granite
768	"	"	17,56	15,10	9,90	0,5	140,0	-	"	amphibolite, mica gneiss
769	"	"	16,01	4,30	3,50	0,4	135,0	-	"	amphibolite, mica gneiss
770	"	"	14,01	7,30	5,00	0,4	120,0	-	"	amphibolite, mica gneiss
771	"	"	13,61	9,50	6,00	0,4	135,0	-	"	amphibolite, mica gneiss
772	"	"	12,79	8,30	5,00	0,3	150,0	-	"	amphibolite, mica gneiss
773	"	"	12,09	8,60	6,00	0,3	135,0	-	"	amphibolite, mica gneiss
774	"	**JTM2**	27,01	5,00	4,40	0,7	-	-	"	mica gneiss
775	"	"	25,01	5,20	3,90	0,7	90,0	-	"	mica gneiss
776	"	"	24,36	6,80	5,50	0,6	135,0	-	"	mica gneiss
777	"	"	21,61	10,70	7,30	0,6	130,0	-	"	granite
778	"	"	15,51	9,20	6,20	0,4	135,0	-	"	mica gneiss
779	"	"	14,11	14,20	8,60	0,4	-	-	"	mica gneiss

780	"	"	12,36	15,30	10,30	0,3	-	-	"	granite
781	"	"	11,01	13,40	9,40	0,3	-	-	"	granite
782	"	"	9,06	2,50	2,60	0,2	120,0	-	"	mica gneiss
783	"	"	7,31	-0,50	1,10	0,2	140,0	-	"	mica gneiss
784	"	**JTM3**	24,61	9,60	6,50	0,6	120,0	-	"	migmatite mica gneiss
785	"	"	20,91	4,90	4,10	0,5	150,0	-	"	migmatite mica gneiss
786	"	"	19,41	4,10	4,00	0,5	140,0	-	"	migmatite mica gneiss
787	"	"	18,21	8,50	4,80	0,5	110,0	-	"	migmatite mica gneiss
788	"	"	17,21	14,00	8,00	0,4	-	-	"	migmatite mica gneiss
789	"	"	15,81	5,80	4,00	0,4	135,0	-	"	migmatite mica gneiss
790	"	"	14,69	10,20	5,90	0,4	130,0	-	"	migmatite mica gneiss
791	"	"	12,29	8,20	5,70	0,3	140,0	-	"	migmatite mica gneiss
792	**STOCKMANN PARKING HEL-SINKI**	**JTM201**	12,40	2,10	2,10	0,3	-	-	2003	mica gneiss
793	"	"	15,80	2,30	2,30	0,4	130,0	-	"	mica gneiss
794	"	"	17,00	6,90	4,80	0,4	135,0	-	"	mica gneiss
795	"	"	19,30	5,20	3,80	0,5	90,0		"	Migmatic granite
796	"	**JTM202**	12,50	4,00	3,30	0,3	150,0	-	"	Migmatic granite
797	"	"	16,20	5,30	3,60	0,4	150,0	-	"	Migmatic granite
798	"	"	23,20	6,70	5,70	0,6	150,0	-	"	Migmatic granite
799	"	"	25,20	3,20	3,20	0,7	140,0	-	"	Migmatic granite
800	"	"	26,00	1,60	1,60	0,7	-	-	"	Migmatic granite
801	**KAMPPI HELSINKI**	**JTM4**	14,10	9,90	5,30	0,4	50,0		2002	Granite
802	"		16,50	5,00	3,60	0,4	60,0		"	Granite
803	"	"	17,80	8,40	4,70	0,5	60,0		"	Granite
804	"	**JTM5**	6,90	4,00	2,90	0,2	130,0		"	Migmatite (mica gneiss)
805	"	"	14,00	3,50	3,90	0,4	40,0		"	Migmatite (mica gneiss)
806	"	"	26,20	10,30	4,40	0,7	170,0		"	Migmatite (mica gneiss)
807	**RAISIO**	**SK3H**	7,20	10,80	5,10	0,2	140,0	-	2001	granite (rough-grained mud-stonegranite)
808	"	"	10,00	8,20	4,50	0,3	120,0	-	"	
809	"	"	17,90	5,40	3,40	0,5	120,0	-	"	

810	"	SK4H	10,70	3,80	3,50	0,3	170,0	-	"	
811	"	"	21,60	11,60	7,10	0,6	140,0	-	"	
812	"	SK5H	7,30	3,90	3,60	0,2	20,0	-	"	mica gneiss/ amphibolite
813	"	"	10,70	8,50	5,40	0,3	60,0	-	"	
814	"	"	16,20	9,60	5,90	0,4	60,0	-	"	
815	"	"	18,30	6,70	5,20	0,5	130,0	-	"	
816	"	"	19,60	12,20	7,20	0,5	140,0	-	"	
817	"	"	21,90	9,30	5,10	0,6	130,0	-	"	
818	**ARKADIANKATU HELSINKI**	**JTM1**	18,50	12,10	6,60	0,5	90,0		2001	granite, fractured
819	"	**JTM2**	17,40	7,10	4,90	0,5	50,0		"	"
820	"	"	19,90	4,40	4,10	0,5	100,0		"	"
821	"	**JTM3**	9,20	2,20	1,30	0,2	90,0		"	granite of uniform quality
822	"	"	12,70	3,80	2,30	0,3	75,0		"	"
823	"	"	16,80	3,80	2,80	0,4	135,0		"	"
824	"	"	17,80	3,30	3,10	0,5	125,0		"	"
825	"	"	19,30	3,50	3,20	0,5	120,0		"	"
826	"	"	21,30	3,80	3,30	0,6	125,0		"	"
827	"	"	22,20	3,70	3,60	0,6	130,0		"	"
828	**HELSINKI SALMISAARI**	**JTM5**	14,90	5,19	**4,65**	0,4	160,0		2000	
829	"	**JTM6**	16,99	7,63	7,05	0,4	120,0		"	mica gneiss
830	"	**JTM7**	8,10	10,79	8,52	0,2	140,0		"	amphibolite
831	"	"	7,20	10,47	9,09	0,2	160,0		"	amphibolite
832	"	**JTM8**	16,03	5,76	4,27	0,4	170,0		"	
833	"	"	11,13	17,92	11,59	0,3	160,0		"	Granite
834	"	"	10,43	15,85	11,59	0,3	105,0		"	Granite
835	**TAPIOLA ESPOO**	**JTM-1**	3,85	6,85	4,69	0,1	145,0		2000	
836	"	"	8,20	4,29	3,91	0,2	60,0		"	
837	**TAPIOLA ESPOO**	**JTM-2**	12,27	10,80	5,76	0,3	15,0		2000	
838	"	"	13,02	4,68	4,23	0,3	90,0		"	
839	"	"	13,62	5,24	3,45	0,4	10,0		"	
840	"	"	17,62	9,54	5,34	0,5	30,0		"	
841	"	"	23,12	5,18	4,32	0,6	150,0		"	

842	**TAPIOLA ESPOO**	**JTM-4**	11,57	4,47	2,95	0,3	0,0		2000	
843	"	"	15,22	4,76	3,70	0,4	40,0		"	
844	"	"	16,27	4,92	3,08	0,4	40,0		"	
845	"	"	17,77	4,12	3,70	0,5	175,0		"	
846	"	"	18,37	6,72	4,41	0,5	160,0		"	
847	**KAMPPI HELSINKI**	**MP1**	6,90	**6,00**	**4,60**	0,2	**135,0**		2000	
848	"	"	16,20	**4,80**	**3,70**	0,4	**145,0**		"	
849	"	**MP2**	10,20	8,90	4,60	0,3	160,0		"	
850	"	"	11,30	3,50	2,20	0,3	-		"	
851	"	"	13,40	**4,60**	**4,20**	0,3	**150,0**		"	
852	"	"	14,40	2,60	2,60	0,4	120,0		"	
853	"	"	17,50	0,60	2,80	0,5	130,0		"	
854	"	"	18,10	**13,10**	**8,10**	0,5	**110,0**		"	
855	**SIPOO NIKKILA**	**MP1**	6,90	**6,00**	**4,60**	0,2	**135,0**		2000	
856	"	"	16,20	**4,80**	**3,70**	0,4	**145,0**		"	
857	"	**MP2**	10,20	8,90	4,60	0,3	160,0		"	
858	"	"	11,30	3,50	2,20	0,3	-		"	
859	"	"	13,40	**4,60**	**4,20**	0,3	**150,0**		"	
860	"	"	14,40	2,60	2,60	0,4	120,0		"	
861	"	"	17,50	0,60	2,80	0,5	130,0		"	
862	"	"	18,10	**13,10**	**8,10**	0,5	**110,0**		"	
863	**SIPOO NIKKILA**	**HM1**	8,70	3,90	3,90	0,2	80,0		2000	
864	"	"	10,45	7,40	4,70	0,3	120,0		"	
865	"	"	12,50	3,90	3,90	0,3	80,0		"	
866	"	"	13,50	6,90	5,10	0,4	80,0		"	
867	"	"	19,90	9,30	3,90	0,5	80,0		"	
868	"	**HM2**	5,10	2,70	2,70	0,1	105,0		"	
869	"	"	6,40	5,30	4,30	0,2	90,0		"	
870	"	"	10,80	5,10	4,10	0,3	90,0		"	
871	"	"	12,60	7,30	5,00	0,3	120,0		"	
872	"	"	14,60	5,30	4,70	0,4	110,0		"	
873	"	"	18,60	5,20	5,00	0,5	90,0		"	

Appendix 3. Separate overcoring measurements usable for the development of Quantitative World Stress Map (Q-WSM). Part of the information in data records.

	SITE	HOLE	DEPTH	SH	Sh	SV	DIR SH	DIR Sh	YEAR	LITHOLOGY
		DIP	m	MPa	MPa	MPa	degree	degree		
1	**HELSINKI HAKANIEMI**		16,00	12,90	9,00	0,1	84,0		2014	granite/granitegneiss
2	**KEMI MINE**		400,00	40,00	17,00	12,0	69,0		2014	albite granite
3	"	"	860,00	41,00	20,00	18,5	104,0		"	albite granite
4	**KYLYLAHTI MINE**		400,00	30,80	22,60	11,2	104,0		2013	skarn
5	"	"	650,00	40,80	20,00	18,5	121,0		2015	black schist
4	**PYHASALMII MINE**		1430,00	65,00	38,00	43,0	127,0		2014	
6	**HELSINKI KALASATAMA**	**JT-201301**	13,07	-	**-**	**-**	-		2014	
7	"	"	13,70	12,10	2,00	**-2,5**	52,7	322,7	"	
8	"	"	14,61	9,90	3,60	**-0,8**	57,4	327,4	"	
9	"	"	15,38	10,70	5,60	1,5	136,3	226,3	"	
10	**HELSINKI MEILAHTI**	**JTM5**	13,39	2,80	0,00	**-2,0**	75,0	29,0	2008	
11	**HELSINKI MEILAHTI**	**JTM1**	20,64	12,50	**5,80**	2,2	132,0	222,0	2005	Migmatite (Granite+mica gneiss)
12	"	"	27,05	12,60	3,50	2,3	123,0	213,0	2005	Migmatite (Granite+mica gneiss)
13	**HELSINKI MEILAHTI**	**JTM2**	11,55	10,30	5,40	0,1	25,0	295,0	2005	
14	"	"	14,51	28,10	**12,30**	4,7	169,0	259,0	2005	Granitic gneiss
15	"	"	18,48	19,60	4,90	-1,1	156,0	246,0	2005	Granitic gneiss
16	**HELSINKI MEILAHTI**	**JTM**	8,90	1,90	**-2,90**	16,7	109,8	199,8	1997	
17	"	**DIP -4**	13,80	9,00	2,70	12,7	164,7	254,7	"	
18	"	"	18,20	3,30	0,30	4,7	13,5	103,5	"	
19	**HELSINKI SPA**	**JTM**	10,35	15,10	9,30	**-2,5**	107,0	197,0	2008	unknown
20	"	**DIP 5**	11,20	15,20	8,60	1,4	131,0	221,0	2008	unknown
21	"	"	18,46	20,60	8,20	1,4	100,0	190,0	2008	unknown

22	**OLKILUOTO-3 OC EURA-JOKI**	**55**	15,67	1,50	0,20	1,9	298,8	173,9	2006	pegmatite granite
23	"	**9,3**	17,46	4,20	0,00	**-4,8**	72,4	41,8	2006	
24	"	**15,8**	18,56	3,00	0,20	1,9	89,3	173,9	2006	
25	**KAMPPI HELSINKI**	**JTM1**	22,19	15,10	4,40	0,2	13,0	283,0	2005	unknown
26	"	"	25,10	5,50	3,00	1,4	39,0	309,0	2005	unknown
27	"	**JTM2**	24,67	7,00	2,40	1,7	154,0	244,0	2005	unknown
28	**KAKOLANMAKI TURKU**	**JMT4**	15,37	18,90	6,30	4,9	92,0	182,0	2003	Granite
29	"	**DIP 90**	16,49	19,30	8,10	3,1	85,0	355,0	2003	Granite
30	"	"	17,44	23,10	8,40	3,9	82,0	352,0	2003	Granite
31	**KAMPPI HELSINKI**	**JTM1**	13,21	-			-		2002	Migmatite (granite + mica gneiss)
32	"	"	14,85	13,20	9,00	1,8	111,0	201,0	2002	Migmatite (granite + mica gneiss)
33	"	"	15,51	-			111,0		2002	Migmatite (granite + mica gneiss)
34	"	**JTM2**	17,63	13,90	8,60	**-1,9**	155,0	245,0	2002	Migmatite
35	"	"	17,63	14,00	9,10	**-1,1**	148,2	238,2	2002	Migmatite.
36	"	"	18,33	16,80	13,10	6,9	139,0	229,0	2002	Migmatite/Granite
37	"	"	20,53	15,70	2,30	0,7	146,0	236,0	2002	Granite
38	"	"	22,14	16,90	7,10	0,1	126,0	216,0	2002	Granite
39	"	"	22,14	20,70	5,90	5,4	133,0	223,0	2002	
40	**HELSINKI SALMISAARI**	**JTM1**	58,13	9,40	2,70	**-1,1**	101,0		2000	Gneiss
41	"	**DIP 90**	68,65	12,50	8,30	1,0	111,0		2000	Gneiss
42	"	"	77,53	11,30	9,00	8,5	160,0		2000	Gneiss
43	"	"	87,18	12,30	8,50	9,1	26,0		2000	Granite
44	"	"	115,58	19,60	13,50	10,6	160,0		2000	Granite
45	**HELSINKI SALMISAARI**	**JTM2**	55,83	15,50	9,80	5,9	50,0		2000	Gneiss
46	"	**DIP 90**	67,48	12,90	6,10	1,9	1,0		2000	Granite
47	"	"	77,41	6,30	3,50	1,4	55,0		2000	Granite
48	"	"	83,14	11,90	1,50	2,7	46,0		2000	Granite/Gneiss
49	"	"	97,05	11,40	2,30	0,2	129,0		2000	Gneiss
50	"	"	115,28	6,50	3,60	6,0	149,0		2000	Gneiss
51	**HELSINKI SALMISAARI**	**JTM3**	53,33	5,30	2,80	3,7	136,0		2000	Granite
52	"	**DIP 90**	70,03	7,70	5,70	**-0,1**	151,0		2000	Granite

53	"	"	79,28	13,90	8,10	4,1	100,0		2000	Granite
54	"	"	89,59	11,20	5,20	5,1	58,0		2000	Granite
55	"	"	103,83	14,80	8,30	7,2	103,0		2000	Gneiss
56	"	"	115,70	17,10	10,60	3,9	120,0		2000	Gneiss
57	**HELSINKI SALMISAARI**	**JTM4**	13,40						2000	Migmatite (Granite+mica gneiss)
58	"	**DIP 100**	14,40						2000	Migmatite (Granite+mica gneiss)
59	"	"	15,40						2000	Migmatite (Granite+mica gneiss)
60	**HELSINKI SALMISAARI**	**JTM4**	13,40						2000	Migmatite (Granite+mica gneiss)
61	"	**DIP 100**	14,40						2000	Migmatite (Granite+mica gneiss)
62	"	"	15,40						2000	Migmatite (Granite+mica gneiss)
63	**HELSINKI VIIKINMAKI**	**MP16**	?	9,00					1999	
64	"	**DIP -3**							1999	
65	**LEPPAVAARA ESPOO**	**R1/98**	11,06	5,40	4,0	4,5	172,0	2,0	1998	Migmatite (granite, pegmatite, mica gneiss)
66	"	"	12,11	5,40	**0,5**	**1,4**	178,0	8,0	1998	Migmatite (granite, pegmatite, mica gneiss)
67	"	"	15,66	2,70	**0,2**	**0,1**	33,0	63,0	1998	Migmatite (granite, pegmatite, mica gneiss)
68	"	"	20,51	2,80	**1,3**	**3,5**	30,0	60,0	1998	Migmatite (granite, pegmatite, mica gneiss)
69	**HELSINKI MELLUNMAKI**	**Rno. 1**	1,60	7,10	**-0,7**	5,8	52,0	152,0	1998	Migmatite (Granite+Mica gneiss)
70	"	"	3,00	16,20	8,50	8,2	89,0	189,0	1998	Migmatite (Granite+Mica gneiss)
71	"	"	4,50	9,20	4,70	4,3	100,0	200,0	1998	Migmatite (Granite+Mica gneiss)
72	"	"	5,80	5,90	3,30	3,3	50,0	150,0	1998	Migmatite (Granite+Mica gneiss)
73	**HELSINKI MELLUNMAKI**	**Rno. 2**	1,60	2,00	0,90	1,6	27,0	127,0	1998	Migmatite (Granite+Mica gneiss)
74	"	"	3,00	9,70	4,30	4,2	84,0	184,0	1998	Migmatite (Granite+Mica gneiss)
75	"	"	4,80	**-1,60**	**-6,80**	**-2,9**	8,0	108,0	1998	Migmatite (Granite+Mica gneiss)
76	"	"	5,90	2,90	1,40	1,8	99,0	199,0	1998	Migmatite (Granite+Mica gneiss)
77	**HELSINKI MELLUNMAKI**	**Rno. 3**	1,80	5,00	**-5,60**	2,8	35,0	135,0	1998	Migmatite (Granite+Mica gneiss)
78	"	"	2,90	5,00	1,00	6,4	111,0	211,0	1998	Migmatite (Granite+Mica gneiss)
79	"	"	4,50	9,80	2,10	5,3	29,0	129,0	1998	Migmatite (Granite+Mica gneiss)
80	"	"	5,60	9,30	**-2,60**	**-7,3**	43,0	143,0	1998	Migmatite (Granite+Mica gneiss)